COTTON SPINNING

COTTON SPINNING

BY

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VOLUME I

INCLUDING ALL PROCESSES UP TO THE END OF CARDING

WITH ILLUSTRATIONS

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PREFACE

THE following pages, which formed originally a series of articles in *The Textile Mercury*, have been written with the avowed intention of supplying to the students of our technical schools the means of gratifying what is undoubtedly a growing desire for the acquisition of knowledge on the subject of cotton spinning. Whilst as a nation we are in a position in many respects to maintain an industrial supremacy, yet it cannot be denied that at present we are passing through a very severe crisis, and unless something is done to keep apace of the enormous strides other countries are taking, and which enable them to compete successfully with our own products, we shall find ourselves lagging behind and losing the advantages we have hitherto possessed.

The keen competition engendered by this state of affairs is resulting in the intensifying of the truth of many economic laws which in prosperous times are too often ignored, but which in their logical sequence prove only too clearly, like the laws of evolution, that the weakest must

go to the wall, the fittest only can survive in the industrial world. Apart from the commercial aspect of the question, there is within most people some desire to gain knowledge for its own sake, for the sake of the pleasure it gives in enabling something to be done well, in fulfilling a duty satisfactorily, or in the exercise of ability when it assists in the performance of a work which is done better than any previously attempted.

Much has been done during the last few years to remedy the shortcomings in our educational system, and the results of these efforts are beginning to make themselves felt, and are widespread in their beneficial effects; technical education is making progress, and several excellent books have been written by men competent to speak with authority, but there is an ever-growing demand for fuller details, increased facilities for reasoning, for opportunities of the development of ingenuity which is fostered by the presentation of the most recent efforts and results, and in addition some encouragement towards a graphic method of conveying our ideas to others. All these demands call for immediate attention, and the present book is given to the world in the hope that it makes a step forward in the right direction towards the satisfaction of the requirements indicated above.

The greatest care has been exercised in bringing every subject fully up to date, and an especial feature has been

made of the illustrations, both in number and quality. It cannot be too strongly insisted upon that all possible incentives ought to be given to students and others interested in cotton spinning, to take advantage of every opportunity that presents itself of sketching for themselves portions of the machines they are studying, and in the following pages this feature has been kept well in the foreground, to such an extent that the author can reasonably claim to have done considerably more in this direction than any previous writer. An endeavour has also been made to bring the text more into line with the educational status of the present day reader, who demands something more than mere description, and who is beginning to understand the subject sufficiently to enable him to see through the fallacies of many of the so-called explanations of its difficulties.

It is a somewhat remarkable fact, but nevertheless a demonstrable one, that cotton spinning has never taken the place to which it is entitled among the other great branches of mechanical science, and this in spite of the fact that it presents probably more difficult mechanical problems successfully solved than any of the other departments to which so much attention is directed; it rests with the rising generation to say whether it can be raised from a mere process into the dignity of an important section of mechanics, and this can only be done by showing that the

subject possesses within itself principles and actions that have the highest claim to attention both from a mechanical as well as a scientific standpoint; there exists a few who are doing their utmost to establish it on a proper basis, and whose work appeals to all thoughtful readers, but only the outskirts in this direction have been touched. Technical education is widening the field of thought and preparing the ground for a more thorough appreciation of its importance, and it is upon the results of such teaching that our future growth and success must be based.

W. S. T.

BOLTON, *November* 1895.

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INTRODUCTION

The enormous changes that have effected the well-being of the world in every direction during the last hundred years, as well as those that are constantly taking place around us at the present time, have crowded so quickly upon us as to prevent us judging adequately of their true relative importance; our being in constant touch with them and surrounded by their effects cause us to fail in conceiving of their magnitude or appreciating their worth at its real value: in this way we loose all sense of proportion, and our estimate of their utility compared with previous conditions is considerably reduced or impaired as a consequence; it is therefore most desirable that a brief review of the history of cotton spinning should be given in order to present in a kind of perspective the order of succession of the great changes that have ultimately led up to its present position.

The cotton industry, which has now spread itself over almost the entire inhabitable globe in its great centres of population, is undoubtedly one of the most potent factors the world has had in its civilising influence, and it has probably done as much or even more in contributing to the welfare of mankind and his progress as any of the other great branches of industry. Like all the important facts of our existence, whether we deal with the formation

of the universe or the building up of a man's character, we must be prepared to recognise in its essentials that all-pervading force known as the law of evolution. The cotton industry is no exception, in its methods of development, to this mighty principle of the universe, and in tracing its history we shall see that there has been a gradual growth, from practically the most primitive beginnings, going on through all the intermediate stages up to its present position. We must be quite ready to acknowledge that there has been long periods of apparently unbroken calm as well as sudden outbursts of energy in its growth; but it does not follow that such erratic actions in its mode of development neutralise the theory of its growth, any more than the sudden shock of an earthquake or the unexpected outburst of a volcano destroys the scientific story of creation; thought and action for long periods may apparently be stationary, but a casual glance at the world's history will show that, no matter how abrupt the introduction of inventions have been which make what might be termed a fundamental departure from previous methods of action, the people have accepted them as an evitable step in the advance of progress, and whilst some have suffered through their introduction and fought blindly against them, their display of ignorance has been but a feeble attempt to keep the world in a state of infancy and themselves in a continual condition of drudgery. In tracing back to its beginnings the story of cotton spinning, we must first try to realise that many of the great difficulties that surrounded the successful formation of yarn had been solved long periods before the principles were applied to the making of cotton, for the use of cotton as a fibre for the purposes of thread-making and weaving is a very recent occurrence compared with

the remote antiquity of other fibrous substances and their manufacture for similar purposes, and it is to these that we must seek for many of the beginnings or steps that have led up to its present position. In the first place, it is highly probable that the coverings used by primitive man as a protection were of two kinds and contemporary in their origin, viz. that afforded by the luxuriant vegetation of the remote ages, and the shelter furnished by the skins of animals; these would be used chiefly as a shelter against climatic conditions, and only after long periods of time would they begin to be used as a distinct covering for the bodies. During this time there would be gradually evolved some idea of connecting two or more pieces of the respective substances together. The vegetable and animal kingdom contain several distinct means of solving this problem, and are of such a nature as to be easily recognised. The grasses and seeds would be taken advantage of at an early period for this purpose, and the forests would present many means of doing the same thing in its climbing plants and the long thin trailing branches of many of its trees; fibres of a finer character would be discovered in due course, when much of the vegetation, after its decay, left the skeleton of its leaves and bark existing as fine filaments which could easily be recognised and put to some use. Those who took advantage of the opportunities or facilities afforded them by the animal kingdom would quickly see the advantages of the fibrous covering of the skins, and some method of tying hairs together to obtain longer strands would naturally follow; stronger forms of bands or ligaments were readily made by cutting the skins into thin lengths, and there would be no difficulty in knotting or tying these together to get any required length; but so far this was not spinning, and the great

problem connected with this feature as yet remained unsolved. Spinning is in its essential the practice of twisting, and in the subject under consideration the name has been appropriated as a description of a complete process, in which a number of loose fibres are bound together as one thread simply by means of a twisting operation. The practice of twisting for such a purpose was unquestionably the beginning and end of the whole art of spinning, and upon it is based the foundation of the industry. In principle it remains to-day what it was in the beginning, and its two great objects, viz. that of bringing into a smaller compass and more orderly condition a large number of loose fibres so as to form a strand, and also by this means to enable the bound fibres to offer greater resistance to being pulled asunder, which resulted in a greatly increased strength, are to-day the chief aims towards which all the operations of a modern cotton-mill try to attain perfection.

It will be quite obvious to even a casual observer that the act of twisting any substance of a fibrous nature has the direct effect of weakening it, and according to the amount of twist given to it the reduction in strength will vary in the same degree and in some fixed proportion. We thus see that in any yarn we find it impossible to obtain the maximum strength of the multiplied individual fibres, and one chief cause of this is the loss of strength owing to the fibres being twisted together; this is by no means a small matter, as the loss in many cases reaches a very high percentage of the calculated strength of an individual fibre. Much remains to be done in the direction of ascertaining the influence of twist on the strength of yarn, and although at present we recognise several rules as to the amount required for certain purposes, it is almost

unnecessary to point out that such a basis is far from being exact or satisfactory.

In twisting a number of fibres together, although each individual fibre is weakened, we must understand that the ultimate strength of the yarn is not tested by strains which act at such a distance apart as the length of the staple, but generally at a considerably greater distance, and in this case the weakness of the collected fibres would be their readiness to slide over each other; it is this weakness that is enormously strengthened by the twisting process. The precise point at which the maximum strength is attained is a very moot point as yet, but it is easily seen that after a certain number of twists are given to the yarn its strength begins to be reduced, and the excessive strain put upon the individual fibres through the distortion of twist, reaches a point where finally the mere fact of carrying the twist a little farther causes rupture.

This all-important origin and foundation of spinning was known and practised from the remotest period of the known history of the world, and, moreover, its many corollaries, or rather the several consequences which would naturally follow the doing of it in as perfect a manner as possible, were also thoroughly understood; the specimens of yarn that have come down to us, and the description of still more remote work to which older writers refer, show us that uniformity of twist was recognised as of vital importance; rotundity of the thread and regularity in its diameter was a feature that was carefully kept in view, and the degree of fineness to which a thread or yarn could be spun is scarcely credible, seeing that even the best machines of the present day are unable to produce better results.

The attainments to which this feature of forming threads

had reached must have been a growth of a very long period, and innumerable steps were no doubt necessary before the intermediate stages and difficulties were successfully overcome. Probably the first means of twisting fibres together would be for some one to take a bunch of hair or strands of bark, and drawing them out into as equal a line as possible, and of a quantity suitable for the purpose in view, and then to take it and twist it by means of the two hands into a band or strand; such a method as this would be somewhat limited in the length to which a rope could be made, and it would be quickly improved by employing two persons to do the work, one to twist at one end of the newly-formed band, whilst the other attended to the equalising of the loose fibres that were being twisted together; this last man would readily see that by laying fibres upon those that were receiving the twist, so as to cause an overlapping, an incorporation of the whole took place, and from the observation of this fact would naturally follow the continual twisting and addition of new material, so that no limit was placed on the length to which a strand could be made. This, it will be noticed, was all hand labour, and necessarily slow and tedious, so there came a time when an improvement was effected in obtaining a quicker mode of twisting; the twisting of different diameters of threads between the two hands would lead to the suggestion that a certain diameter seemed to be easier to turn with the least fatigue to the worker, and from this would come the improvement of using a short rod of suitable diameter, and to the end of which the twisted strand would be hooked or fastened; an improvement on this would be made when advantage was taken of a bent piece of wood, shaped in such a manner that if simply held loosely in one hand the twists could be put in by the turning of

the other end; it is easy to conceive of a variety of circumstances that would suggest such a course, and it must have been a comparatively early mechanical means of effecting the result; most probably for a long period this would represent the highest point capable of being reached in the spinning process, and even to-day for work of a casual nature, such as the forming of rough bands, etc., we find it very frequently employed. We now come to a stage in the history, nearer to our own time, and one mere conjecture gives place to positive fact, where the order of successive steps can with tolerable certainty be pointed out, and where distinct claims to invention can be made. So far the progress has been apparently very slow, and has spread itself over long ages of the world's history; but, nevertheless, each step has been a fundamental advance upon its predecessor; the effect of twist was one of the greatest discoveries of any century, and the various methods of obtaining it were distinct and sound inventions, and no mere details of working. The crank applied to the purpose, whether it was original or not, so far as its other uses were concerned, must have caused what might be termed a revolution in the trade; and, together with all this, there would be going on a gradual building up of knowledge as to the requisites for making a perfect thread, all of which would be but a preparation for the further improvement which followed.

The next great step was the devising of some means whereby a reduction in the number of the hands employed could be obtained. Hitherto it required two people to produce the yarn; this was an inconvenience, and efforts were made to overcome it. It must have been noticed at some time that the occasional accidental slipping away of the twisting stick from the hands of the twister at the be-

ginning of the spinning operation would cause all the twist to be taken out, and the momentum of the hanging stick would enable it to continue turning and to put twists in in the opposite direction. Some ingenious mind would take advantage of the suggestion offered by this action, and very soon the world was treated to a means of spinning in which only one person was necessary. The way it was done was by using a species of spindle with a nick or slit at one end; a portion of the fibres of wool most probably was fastened in the slit, and the spindle hanging down was set revolving by one hand, whilst the other fed or pierced up the fibres to form the thread. When a sufficient length had been made, the twisted portion was wound on the spindle and its end again fixed in the slit, and another length made in the same way. This went on until a spindle was full. In several parts of the world, but notably in the country districts of South America, this system of spinning is extensively practised, with only slight variation of details from that described. The girl or woman during a walk carries out with her a stock of wool or cotton and her spindle, and whether standing, walking, or sitting, her spinning is always going on and her spindle filling. Several details were added which improved this spinning process, notably the one where the weight of the spindle was recognised as an important factor in the maintenance of its revolution; we therefore find that a heavier spindle was used, or its weight increased, by an additional weight to give it a momentum. The method of carrying the loose fibrous substance was found to be inconvenient, and after a time a preliminary process in the winding in a very loose condition of the wool upon a long stick was employed. This stick is known as a distaff, and though not a necessary adjunct,

yet its usefulness came to be generally acknowledged and extensively used.

So far, the description has given processes in which no mechanical power had been called in to produce the result, with the exception of the crank; but in course of time the pulley and its multiplying power of speed was taken advantage of and introduced. The crank was quickly displaced, and a reversion made to the old hook and stick; but instead of turning it with the hands, a band was passed round it and over a large pulley in such a way that one revolution of the latter caused the stick to revolve a number of times, according to their relative diameters. Two people would be necessary to work this primitive machine at first; but very soon it would be found an easy matter for the man who fed the loose wool to revolve the pulley himself by having an endless band connected with it, and which he drew along as the yarn was spun. Such a system as this is still generally used in various parts of Europe, especially in Germany, and large quantities of ropes, etc., are manufactured by the process.

Following upon this discovery came the recognition of what is the basis of our modern mule spinning. Hitherto either a hook or slit in the spindle end had been used to fasten the thread whilst spinning was taking place. Some observant mind noticed—what must have been a very frequent occurrence—that if the thread was moved out of a straight line with the axis of the spindle, and at the time became loose from the slit, the spinning continued, and twists were put in just the same. The reason for this is not far to seek. If yarn is held at an angle, the spindle in revolving will naturally attempt to wind it on; but in doing so the thread travels up the spindle till it reaches the point, and here it slips over. If the revolution

is continued, this slipping over the end of the spindle is repeated, and every time it happens a twist is given. Apparatus incorporating this improvement were largely used. A large pulley, moved by the hand of the worker, drove a small pulley on the spindle; a distaff containing the loose fibres was supported on the lap or the floor, and the material guided at an angle on to the spindle. In this position the twists would be put in, and after a suitable length had been spun, the pulley would be reversed and the yarn wound on the spindle. Other forms of spinning machines, differing from this in the method of twisting and winding, are in existence, and even in use, showing clearly the advances that have been made in our modern systems, especially in the details. The continuous spinning and winding of yarn by means of a flyer is a very old means of working, and yet its persistence has been remarkable.

It must be understood that it is more than probable that most, if not all, the improvements pointed out were made in connection with the manufacture of wool or some species of long fibrous vegetable material; but when cotton came to be acknowledged as a suitable substitute for other fibrous substances, adaptations would readily be made to render them capable of treating such a delicate and short fibre. The freeing of the cotton from the enclosed seeds exercised the ingenuity of several nations, especially India, and labour-saving devices were employed to dispense with the tedious and slow process of hand-ginning. At first an iron or wood roller was placed upon a heap of seed cotton, and by means of the feet a native would move it backwards and forwards, at the same time exercising as much pressure as possible. This would have the effect of forcing the seeds away and leaving the fibres com-

paratively free. It was of necessity a very slow process, and a great advance was made upon it when the churka was introduced. This machine consisted of two rollers of unequal diameters and each running at unequal speeds; the small top one, generally made of iron, revolved much quicker than the large wooden bottom one. The effect of this is such that the fibres of cotton are drawn through the rollers, leaving the seeds behind, the space between not permitting them to follow. Six to eight pounds of clean cotton could be obtained per day, and it is still extensively used in India.

After the introduction into Europe of the common or Jersey spinning-frame, about the year 1530, and the more recent improvement upon it in the flyer spinning-frame of Saxony about forty years later, a great demand sprung up for some kind of preparing operation which would enable the cotton to be spun with a less degree of care and skill than formerly. This meant that instead of having a mass of the fibres and taking small quantities from it as the spinning progressed, and exercising great care in doing this so that a uniform thread would be spun, if the fibres could be formed into some kind of regular order and made more free from the entanglements that always existed, it would lessen the skill required, and thus enable many people to do the work who were otherwise incapable of it.

Cotton has from time immemorial always been subjected to a cleansing action after its separation from the seeds, principally by means of an elastic bow, which acted almost like a whip and flipped the cotton about in a way that forced from it much of its broken seeds, leaf, stalk, sand, etc. But now another process was required, some kind of combing action was demanded, and, as on

other occasions, recourse was had to the means used for a similar purpose in the wool industry. The cotton was placed upon a short length of boarding covered with a number of needles. Over it was placed a corresponding board or card, as it was termed, and by drawing this over the lower one the cotton was dragged through the needles. This was done several times, until it was found to be fairly well opened. It was then lifted off as a thin fleece, and in this form could easily be made into a thick sliver for the spinning-machine. The various fleeces were pierced up, and continuity in the length of the yarn obtained.

The next step was to adopt some means of drawing out this rather thick sliver by a mechanical arrangement, as it was found to be a very slow process when performed during the twisting. Out of this necessity was developed one of the most important principles upon which success in spinning depends, viz. the drawing-out process by means of successive lines of rollers running at accelerated speeds. Wyatt, in 1738, through the medium of Lewis Paul, was the first to employ rollers for this purpose, and to him ought to be given the credit due to one who displayed such original ingenuity in the establishment of a fundamental basis for future progress. Through some cause or another very little was done to persevere in their use, and it was not until Arkwright, in 1769, recognised its superiority over existing methods that it came to be a fixed feature in cotton spinning; he perfected its adaptation to the purpose of drawing the fibres, and in various ways did so much to make it successful that it came to be thought that Arkwright was the original inventor. He aided this view himself by incorporating it in a patent which he took out in 1769, but it was too palpable a copy, so much so that

on one memorable occasion when he tried to insist on its validity a jury refused to sanction his claim.

The year 1748 is notable as the one in which two important improvements were effected in the carding of cotton. Lewis Paul and Daniel Bourne both made great strides in improving the output of the carding operation, each used a cylinder covered with needles, and upon which was superimposed a covering of similar needles, between which two surfaces the cotton was passed; it was afterwards stripped off by means of a hand-comb and then pieced up to the previous length. This was greatly improved by Hargreaves somewhere about the year 1762, who tried to card the cotton by passing it between two revolving cylinders running almost in contact with each other; he also added a doffer for stripping the cotton from the cylinder, but it resulted in failure.

Other details of the card were rapidly added. In 1772 Lees gave to it a feeding arrangement in the form of an apron, and almost at the same time Arkwright introduced the cotton in the form of a lap. Other improvements were also made by Arkwright—notably the doffer and doffing-comb, which stripped the cotton from the doffer in a continuous fleece, in which form it was gathered together, and after being passed through a conical opening was carried forward and placed in a revolving can or coiler, though this latter differed from the one in use at the present time. Innumerable details of a very important character have been introduced into the card, many of which are quite recent, but as a machine in its essential principles and actions it differs little from that used in the beginning of the century, and to the men who then had its inception belongs the credit of its future importance.

Contemporary with this advance of the card must be

noticed a similar if not greater progress in the spinning frame, chiefly owing to the large demands for yarn in consequence of Kay's improvement of the loom in 1738. This advance followed the two great principles of spinning shown in the common spinning wheel: twisting from the spindle point, and the Saxony method, in which a flyer and bobbin were used.

Hargreaves, between 1764-67, invented a machine called a spinning-jenny, capable of working a number of spindles through bands driven from a cylinder. He kept to the old method of drawing the cotton out by a receding motion limited to a certain length, and then after twisting, winding on the yarn during the return of the frame carrying the spindles. The horizontal position of the spindle was, however, made vertical in this machine, and in this position it has ever since remained.

Arkwright, working to improve the flyer spinning-wheel, achieved an equal success when his machine was given to the world in 1769. He, however, borrowed freely from previous inventors, but it must be allowed that apparent failures in other hands were turned into successes when adopted by Arkwright.

His machine is chiefly characterised through his employment of rollers for drawing purposes, and the great advance he made in the performance of details requisite to successful and quick work. A traverse arrangement was given to the bobbins so that they were built up automatically, and the means of doing this effected by employing a can. The machine was termed a water-frame, because at this time water power was the means used to drive them.

The two main features of these machines, viz. the drawing rollers of Arkwright's frame and the stretch and twisting arrangement of Hargreave's jenny, were joined

together in the invention of Crompton of 1779. When the modern mule first saw light, whilst incorporating the best features of each of the previous machines, his own inventive faculties were given full play and several novel and ingenious elements introduced, notably the fixing of the creel as part of the framing and the placing of the spindles on the moving carriage.

Hargreave's jenny suffered greatly owing to the enormous success of Crompton's mule, but it was turned to other uses as the preparing frame for the roving to be used in spinning, and after considerable improvements it was enabled to again compete with the mule for certain classes of work.

The mule continued to be improved by added details, but it still remained a machine that required manual labour, and that of a very skilful kind. Efforts were therefore made in the closing decade of the last century to remedy this by means of an entirely automatic action. The headstock had already been placed in the centre of the spindle carriage, and a squaring band used to maintain the carriage in a straight line as it moved in and out and so neutralise the deflection. But it contained many defects, for which its growing use demanded a remedy. Several attempts were made, all of which more or less ended in failure, until Richard Roberts of Manchester took the matter in hand. It was a long struggle, for after his first patent in 1825 it was five years before a machine was made capable of fulfilling the work demanded of it. Ultimately, however, it proved successful, and from it we date the birthday of our present self-actor mule. In it we have the solution to most of the problems presented in such a complicated piece of mechanism as the hand-mule was. The winding was performed in a distinctly novel

manner by means of a quadrant; the counter and copping faller wires were arranged to work in unison; the backing off and drawing up was practically as we have it to-day, and the shaper or builder motion gave to it an incalculable value as a labour-saving appliance and productive machine. The employment of the scroll, though by no means novel, was yet so far improved as to merit such a description, and it gave to the carriage such a control of movement as to be scarcely creditable. Constant improvements have been made in important details, but nothing that has been done can compare with the wonderful result of Roberts' labour. It has been truly described as "one of the greatest triumphs of mechanical genius that has ever been achieved," and in the harmonious working of its many and various actions and the compactness of its parts, we can still point to it, even among the many ingenious mechanical productions of the present day, as one that may claim to be excelled by none whether judged by a mechanical standard or by its results.

Whilst the mule was being evolved out of the primitive machine which preceded it, great advances were being made in the other machines used in the preparatory processes. The gins in use were unable to do the amount of cotton necessary to supply the demand, and so we find that this machine received considerable attention. But nothing of importance was done until Eli Whitney, in 1793, introduced his saw gin, which worked a complete revolution both in the social and commercial condition of America, and gave a production that, for the time being, amply supplied the wants of the world.

The scutching machine is an advanced mechanical method of freeing the cotton of dirt, etc., and although the operation started as a bowing process and passed on

through primitive forms of willows, it was not until Mr. Snodgrass, in 1797, invented a machine somewhat on the same lines that our present day machines are worked. Many details of great importance were subsequently added, such as cages, fans, lap parts, and regulating motions. This latter improvement is one of the most important ones the machine has had applied to it, and to Mr. Lord is due the credit, he having patented it in 1862. For a long number of years it was known as Lord's piano motion.

The drawing frame was a natural result of the drawing process, and was early recognised as a distinct operation. Arkwright saw its advantages, and he also applied it for the same purpose that the flyer frames are used at present. He obtained the twist by causing the can, into which it was delivered, to revolve quickly, and by another process winding it on bobbins ready for spinning. These two separate actions were soon after combined into one by placing the bobbins in the revolving can and giving to it a turning motion. Arkwright, however, very soon saw the advantages of the old Saxony flyer spinning-wheel for the object he had in view, and very quickly a machine was made incorporating his ideas. The bobbin and flyer were both driven positively, but he was unable to satisfactorily overcome the difficulty of giving the bobbin a varying speed according to the diameter that was being wound, and it was not until Green, in 1823, invented several methods of doing it, but they were clumsy and inadequate. Arnold, in 1822, effected a radical alteration in the means then employed, but his invention was ignored until Houldsworth, three years later, incorporated its principle in his own patent differential motion. This motion, sometimes called the sun and planet motion, came to be the chief means employed through which the driving of the

bobbin was effected. About the same time two cone-drums began to be employed for reducing the speed of the bobbin as its diameter enlarged, or *vice versâ*.

The flyer throstle quickly developed into a complete and effective machine, and although an effort was made to improve it by Danforth, it was not until the invention of the ring-spinning system, about 1828, that it began its retrograde movement. At the present time improvements, principally in detail, are being constantly introduced, and although no radical change can be expected of the present system of spinning, there is at least hope that in the future many complications that at present exist will be dispensed with and more simple and better methods take their place.

CHAPTER I

THE COTTON FIBRE

COTTON is the name given to the product of a class of plants which have, as a process of Nature, evolved out of themselves a method of perpetuating their kind by a distinct system in the distribution of their seeds. We find throughout the vegetable kingdom a large variety of wonderful means employed by plants in serving this purpose, and that adopted by the cotton plant is no exception, for it is both ingenious and effective. Its seeds, encased in a pod, are in groups, and during their development, after the disappearance of the flower, they become gradually surrounded with a soft downy fibrous substance. This growth continues until they arrive at maturity, when the excessive pressure within the pod, produced by the masses of fibres and the enlargement of the seeds, causes the pod to burst—a ball of whitish fibres is thus brought to light, and if Nature was permitted her way, this would enable the wind to distribute the seeds in every direction, and to carry them considerable distances, where they would find a suitable place for growth. This fibre is commercially a very valuable substance, and though from time immemorial it has been employed in the making of cloth for various

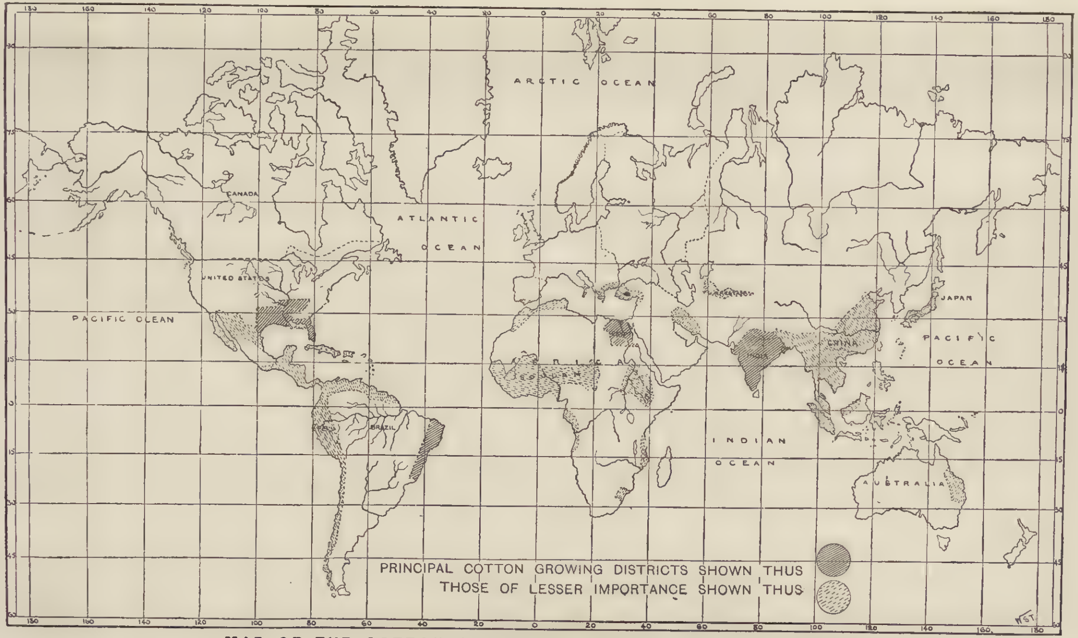
purposes it was not until mechanical methods were introduced of performing the necessary operations leading up to the finished material, that its cultivation was commenced on a large scale, and its quality greatly improved by the adoption of scientific principles in the choice of district, soil, climate, species, and fertilisation as aids to its successful growth.

The cotton plant is scientifically known as Gossypium, and the group of plants to which it belongs, or the family of which it is a member, is that of the Malvaceæ or Mallows. The greater part of the world is suitable to its growth, but commercially it is practically confined between the 40° North latitude and the 30° South latitude—the accompanying map of the world (Fig. 1) enables this to be seen at a glance; and we can also understand from it, in the diversity of climate and country that is there presented in such a vast belt of the globe, what a variety of species of the plant must exist. Botanists differ greatly in the enumeration of the principal divisions of these varieties. The classification in favour for general purposes is the one where they are all grouped under the four following heads: Gossypium Barbadense, Gossypium Hirsutum, Gossypium Herbaceum, and Gossypium Peruvian.

Under these names we give below a list of most of the cottons of commerce, the names of the district in which they are grown being generally adopted in denoting them.

Botanical Varieties

Gossypium Barbadense.—Sea Islands, Florida Sea Islands, Figi Sea Islands, Tahiti Sea Islands, Laguayran Sea Islands, Peruvian Sea Islands, Gallini.



MAP OF THE COTTON GROWING COUNTRIES OF THE WORLD

FIG. 1.

Gossypium Hirsutum.—Uplands, Mobile, Texas, Orleans, White Egyptian.

Gossypium Herbaceum.—Brown Egyptian, Smyrna and Greek, Hingunghat, Dharwar, Broach, Dhollerah, Oomras, Coomptah, Scinde, Bengal, Tinnevelly, Western or Madras.

Gossypium Peruvian.—Brazilian and Peruvian cottons are almost all classed under this head.

A detailed description of each class of cotton, together with their characteristic features, will now be given, and as a variation from the above list they will appear under their general commercial title, which they receive from the country of their growth, as a distinction from the names of the varieties whose names and characteristics follow and are those of districts. The chief countries from which we receive our cotton supply are Egypt, America, Brazil, and India. Other large tracts of country in various parts of the world grow cotton very extensively, as shown in the map, but it is used principally by the natives themselves, so that for practical purposes we may say that exportation to Europe in large quantities is confined to the four countries named.

Sea Island Cotton

Sea Island came originally, it is supposed, from Barbadoes, hence the name Barbadense. It is the most valued species of cotton, and is grown in the southern portions of the United States, on the Carolina and Georgia coasts as well as the islands lying off the mainland. It has a long, fine, soft, and silky fibre, which unfortunately suffers rather severely in some of the future processes, especially Ginning. It varies very little in length or twist, and immature fibres are not frequently present. Its colour is of a light creamy tint. Great care is taken in its cultivation, and as a rule

it is very clean, and free from the impurities caused through careless picking. The climatic and agricultural conditions under which it is grown tend to produce the above excellences, and it quickly deteriorates if an attempt is made to grow it in districts where these favourable circumstances do not exist to the same extent, though even then its fibres are still of a superior kind. Yarn in twist or weft up to the finest numbers can be spun from it.

Florida Sea Island.—This cotton is somewhat similar to Sea Island, being grown from the same seed, but on the mainland of Florida and adjacent states. It has a smooth, bright, silky appearance, but a large percentage of immature fibres prevents it being used for the highest numbers of yarn, its limit in this respect reaching about 200^s; unless for special purposes, it is not used for lower numbers than about 140^s twist or weft.

Fiji and Tahiti Sea Island.—Grown on the Fiji Islands in the Pacific Ocean. The fibres of this variety are more irregular in length than the preceding, but attain a greater maximum length; other defects, such as the presence of immature fibres and irregularity in the twists, however, reduce its value considerably.

Peruvian Sea Island.—Grown on the western coast of Peru from Sea Island seed. It has a slight brownish tint and its fibres are fairly strong, but in appearance it is inferior to Sea Island, and is quite 20 per cent less in value than Fiji; it is occasionally very dirty through careless picking. Though Dr. Bowman states that up to 200^s can be spun from it, it is very seldom that 150^s are exceeded.

All the above classes of Sea Island cotton have a yellow flower, and seeds that are small and black; they are also free from the undergrowth of short fibres, which are present

in many other varieties of cotton, and which materially lessen their value.

Gallini.—An Egyptian cotton, originally grown from Sea Islands seeds, is of a golden tint, and possesses characteristics which render it a valuable commercial cotton. The undergrowth of fibres mentioned previously has developed in this cotton, and prevents its use for the higher class of yarns, which it would otherwise be capable of forming, unless recourse is made to combing, when the shorter fibres are eliminated. It is very strong and tough, and silky in its appearance. 150^s counts is the usual limit in spinning both twist and weft from it.

Brown Egyptian is of a different species than Gallini, and is slightly darker in colour, hence its name. It is most probably a native of the country, and although highly cultivated both in the delta and valley of the Nile, remains inferior to Gallini. It is, however, strong and elastic, and though comparatively free from foreign matter, it contains a quantity of short fibres which are a disadvantage in the preparing processes, where excessive waste may be made. The usual range of yarns spun from this cotton is from 50^s to 100^s twist and weft; occasionally this is exceeded for special purposes.

White Egyptian.—Nominally classed as G. Hirsutum, but in reality a compound of this with G. Peruvian, American and Peruvian seed having combined in its production. White is the prevailing colour, though a brownish tint appears in some of the higher grades. These grades are of a variable quality, some being very clean, others rather dirty; on the whole the fibres are strong and pliable, and the regularity in their length enables good yarn up to 70^s to be made in twist and weft.

Brazilian or Peruvian Cotton

Rough Peruvian.—A native cotton of Peru and Brazil. It is perennial, growing several years in succession, the second and third years' crops being the best. Its colour is light cream, and its fibres are harsh and wiry to the touch. which characteristic enables it to be mixed with wool. It has a good appearance, and is generally very clean. Its use is limited to 70^s for twist only.

Smooth Peruvian differs in feel and pliability from the above, and is not quite as strong; its colour, dull white to cream, enables it to mix well with Orleans; its soft character renders it suitable for weft up to about 70^s.

Maranham.—From the north-east coast of Brazil, has a dull golden appearance, and is rather dirty in foreign matter, its feel is harsh but elastic. It mixes well with Egyptian and American cotton when the colour permits, 50^s twist and weft.

Pernambuco.—The best Brazilian cotton, both in length, diameter, strength, and twist, this latter feature being remarkably regular; it is harsh and wiry compared with other cottons, and consequently is used chiefly for twist yarns. It is mixed largely with White Egyptian. 60^s twist is the extent of its usefulness in yarn.

Cera, Pariba, and Maceio compose a very large portion of the Brazilian cotton crop, the better grades are fairly clean. Its staple is variable in length, whilst its general characteristics are similar to Peruvian yarn. Up to 50^s twist or weft are spun from it; when mixed with White Egyptian, higher numbers than these can be obtained.

American Cottons

American cotton is the staple cotton of the world, and is grown in a number of the States in the south of North America. Its general excellence is accounted for by the peculiar suitability of the soil, the humidity of the atmosphere, the uniformity of its temperature, and the high state of its cultivation. Its character as the "typical cotton" is not given to it for any of the highest qualities cotton possesses, but because it is produced in such immense quantities, and is of a character that renders it suitable for use in innumerable directions by people throughout the world. It is quite natural to find a variety of classes or grades of cotton existing in such a large tract of territory, the various districts, or natural features of the district, giving their names to the classes grown within their boundaries.

Orleans.—The most important of the American cottons is grown principally in the plantations of the Mississippi and Louisiana. It is wonderfully clean and easy to work, and though differing greatly in its grades in different seasons, its better qualities maintain a fairly regular staple. Its colour is mainly white, which develops into a faint cream in varieties. Its fibres are sufficiently strong for ordinary purposes, being also soft and elastic, rendering it extremely suitable for twist and weft up to about 50^s counts.

Other American varieties, as well as Egyptian and Peruvian cotton, are easily mixed with Orleans owing to their similarity in colour.

Uplands, grown on the elevated portions of Georgia, Carolina, and other States adjacent to them, is a cotton possessing characteristics suitable for weft yarn, as it has a soft, moist, and pliable fibre, though not very strong.

Its colour is white, with variations to light cream, and can consequently be mixed extensively with other cottons. As a rule it is fairly clean, but it contains numerous partially developed fibres.

Texas, from the State of that name in the Gulf of Mexico, ranks almost on an equal footing at the present time with Orleans in its general quality.

Its colour is a light brownish tint, otherwise its characteristics are very similar.

Mobile.—An inferior cotton, though exported in large quantities. It is used for numbers from 10^s to 25^s principally weft yarns. Surats and Indian cottons are frequently mixed with it. Considerable quantities of impurities, both natural and foreign, are found incorporated with it in the bale.

Indian Cottons

Indian cottons may be divided into three classes, viz. native varieties, varieties grown from American seed, and several kinds grown from Egyptian and Sea Island seeds. They are all of a rather poor quality, probably owing to the great heat, and lack of the necessary uniform humidity which the plant requires.

Hingunghat.—This is a superior kind of Indian cotton grown in the Central Provinces, and receives a little more attention in its cultivation than some other classes. It is rather dirty, but very strong; and although it varies greatly in diameter, a good yarn can be made of it when cleaned. Colour may be described as a light golden tint. Its yarns range up to 32^s twist, but mixed with American 40^s may be reached.

Dollerah, grown in the Bombay Presidency in very large

quantities, is dirty, and contains a quantity of material impurities. The colour is whitish, and not very strong. Up to 24^s weft can be spun from it.

Broach, also from the Bombay Presidency, takes rank after Hingunghat, and is of a brownish colour, and fairly clean. 28^s twist or weft.

Tinevelly, from the south of Madras, is cultivated extensively under favourable conditions of climate. It is very strong and elastic, whilst its colour is a dull creamy tint, and fairly clean, especially in the better grades, 28^s twist.

Dharwar, a Bombay cotton having a short fibre, but in general similar to the former. 20^s twist or weft.

Oomrawuttee contains large quantities of impurities, resulting in waste when worked. The resulting yarn is good, but not equal to Broach. Its strength is above the average. A creamy colour is the general tint. 20^s twist or weft.

Comptah.—The Central Provinces produce this cotton, which is rather weak, and extremely dirty. It can be made into yarn, chiefly weft, up to 30^s, and has a brownish tint. Very little twist found, and the fibres are dry and brittle.

Madras or Western is of good strength; broken and undeveloped fibres are, however, common. Its other characteristics are similar to Comptah, but is not used for higher than 20^s.

Bengal.—A very inferior and dirty cotton. It is also coarse, harsh, and wiry, though strong. 15^s is the usual limit in spinning.

Scinde.—Of a dull whitish colour, and fairly strong. Good yarn up to 12^s can be made from it. It is generally cleaner than most of the preceding varieties.

China cotton is a rather short species, and is used chiefly in the country itself, the same remark being

applicable to Japan, which grows a large quantity for home use.

Russia obtains a very large supply of the cotton she uses from Turkestan. The inhabitants of many other parts of the world have turned their attention to the better cultivation of what has been with them a very old industry, and much of it is being exported locally to adjacent countries, though it will probably be a long time before it can compete with the well-known and established varieties already enumerated.

In the following table an attempt is made to present the length and diameter of the various classes of cotton as ascertained by several authorities :—

Table of Lengths and Diameters of the Cotton Fibre

	Lengths in Inches and Decimals.					Diameters in Decimals of an Inch.					
Name.	Evan Leigh.	Monie.	Alcan.	O'Neill.	Des-champs.	Bowman.	Evan Leigh.	Alcan.	Roney.	Monie.	Des-champs.
Sea Islands	1·62	1·8	..	..	..	..	·00064	·00025 to ·00056	·000437	·C00135	·000256
Edisto	2·2	..	1·37 to 1·57	1·35 to 1·88	2·28	2·2	..	..	..	..	..
Wodamalam	1·63	..	..	1·44	..	..	..	..	..	..	..
John's Isle	1·6	..	..	1·5	..	..	..	..	..	..	..
Florida	..	1·65	..	..	..	1·95	..	..	..	·000637	..
Fiji	..	1·87	..	..	2·01	1·88	..	..	..	·000637	·000677
Tahiti	..	1·5	..	..	..	1·88	..	..	..	·000641	..
Peruvian	..	1·56	..	..	..	1·5	..	·00052 to ·00078	·000437	·000675	..
Egyptian	1·41	..	1·1 to 1·51	1·13 to 1·18	1·25	..	·000655	·00065 to ·00078	·000437	..	·000763
Gallini	..	1·43	..	..	..	1·5	..	..	..	000·675	..
Brown	..	1·31	..	..	..	1·4	..	..	..	000·738	..
White	..	1·25	..	..	..	1·25	..	..	..	·000769	..
Smyrna	..	1·0	..	..	..	1·24	..	..	..	·000769	·00103
Brazilian	..	..	..	..	..	..	·00079	·00065 to ·00078	..	..	..
Maranham	1·15	1·06	..	1·12 to 1·2	..	1·15	..	..	..	·000787	..
Pernambuco	..	1·25	..	1·18	..	1·35	..	..	..	·000787	·000819
Surinam	1·17	..	1·06 to 1·18	..	..	..	..	..	..	..	..
Pariba	1·2	..	1·11	..	..	1·2	..	..	..	..	..
Cera	1·15	1·03	1·11	..	..	1·15	..	..	..	·000787	..
Maceo	..	..	1·11	..	..	1·2	..	..	..	..	..

Peruvian Rough	1·3	1·28	0·86 to 1·18	..	1·13	1·3	..	..	..	..	·000846
Smooth	1·3	1·28	0·86 to 1·18	..	1·13	1·35	..	..	..	..	·000846
Algiers	1·45	..	1·41 to 1·57	..	..	..	..	..	..	..	..
West Indian	1·3	1·22	..	..	..	1·3	..	..	..	·000769	..
American	..	..	..	..	..	..	·000775	·000874	..	..	·000826
Orleans	..	1·03	..	..	..	1·1	..	..	..	·000757	..
Uplands	..	·93	..	..	..	1·0	..	..	..	·000763	..
Texas	0·92	1·0	..	..	..	0·95	..	..	·000547	·000763	..
Mobile	1·05	0·87	..	1·03	0·92	1·05	..	..	..	·000763	..
Georgia	1·05	..	..	1·03	0·92	..	..	·00025 to ·00056	..	..	..
Mississippi	1·1	..	0·7 to ·98	..	1·03	..	..	..	·000547	..	..
Louisiana	1·1	..	0·82 to 1·05	·97 to ·99	..	..	..	..	..	..	..
Tennessee	0·98	..	..	1·0	..	..	..	..	·000586 to ·0006	..	..
African	1·15	1·03	..	1·1	..	0·91 to 1·25	..	..	..	·000819	..
Indian	..	..	..	..	..	..	·000844 to ·00073	..	·000736	..	..
Hingunghat	..	1·03	..	..	..	1·2	..	..	..	·000833	·000787
Dhollerah	1·1	0·93	1·06 to 1·96	·092 to ·94	0·9	1·1	..	..	..	·000847	..
Broach	0·82	0·84	·78 to ·82	..	0·78	0·9	..	..	..	·000833	·000885
Tinevelly	·75 to 1·05	0·87	..	..	..	0·95	..	..	..	·000826	..
Dharwar	0·98	0·81	..	..	..	1·0	..	..	..	·000826	..
,,	1·0 to 1·65	..	1·18 to 1·37	..	..	..	..	..	..	..	..
Oomrawuttee	..	0·9	..	..	..	1·0	..	..	..	·000847	·000846
Comptah	..	0·87	..	0·9	..	1·05	..	..	..	·000847	..
Madras, West	·85	0·87	·71 to ·9	..	0·82	1·0	..	..	..	·000833	·000885
Scinde	..	0·65	..	..	..	1·0	..	..	..	·00084	..
Bengal	1·15	0·87	..	..	..	1·1	..	..	..	·000869	·000996
China	..	..	·83	..	0·86	..	..	..	..	..	·000949

It would be a somewhat difficult matter to say under which name the most reliance could be placed, as each one has investigated the matter conscientiously, but to a critical observer there is much internal evidence, both in the measurements themselves and their comments on them, to lead to the supposition that thoroughly scientific methods have not been employed in the work. It is natural to suppose that different seasons' crops will contain variations in the fibres according to the conditions under which the plant is cultivated, but only in very extreme cases is the difference in the two factors tabulated of any consequence. Other characteristics of the cotton are modified, and affect its value, but these two are fairly constant. In examining the tabulated results of the authorities quoted, we find that a maximum length has been found in the different classes, and also a minimum one,—after each has probably measured a number of fibres of each class. Much has been made of these results by some writers as giving a comparison for the extreme variation in lengths and diameters, but it is scarcely necessary to point out that such conclusions are of little if any practical use. The chief interest in the matter centres itself in the mean or average length of the staple, and on this we are presented with a strange feature in looking over the tables mentioned. We reproduce tabulated results of two authorities in order to show clearly what is meant :—

LENGTHS OF FIBRES

Description.	Evan Leigh.			Monie.		
	Max.	Min.	Mean.	Max.	Min.	Mean
New Orleans .	·88	1·16	1·02	1·125	·937	1·03
Sea Islands .	1·41	1·8	1·61	2·0	1·75	1·875
Pernams . .	1·5	1·2	1·35	1·375	1·125	1·25
Egyptian . .	1·3	1·52	1·41	1·375	1·125	1·25

The mean length, it will be seen, is exactly the mean between the maximum and minimum; such a result is most unlikely to happen, and to any one accustomed to making investigations for averages, grave doubts are thrown on conclusions represented in this manner. The mean diameters are found in a similar manner; and to show that such a method is likely, and does lead to error, I give twenty-four measurements made by Mr. Midgley, F.R.Met.S., Bolton, from samples of Egyptian taken in four different years—

·0008	·00025	·00065	·00020	·0030	Max. ·00080
·0002	·00035	·00035	·00030	·00270	Min. ·00020
·0004	·00055	·00050	·00035	·00245	2) ·00100
·0005	·00065	·00025	·00070	·00260	Mean ·00050
·0006	·00050	·00030	·00060	24) ·01075	
·0005	·00040	·00040	·00045	Mean ·000448	
·0030	·00270	·00245	·00260		

The average mean of all the measurements, which is the only correct way to obtain the mean, is seen to be ·000448, whilst the mean of the maximum and minimum gives an advance of over 10 per cent on this result.

A far more useful table of lengths and diameters would be one obtained from specimens of cotton after passing

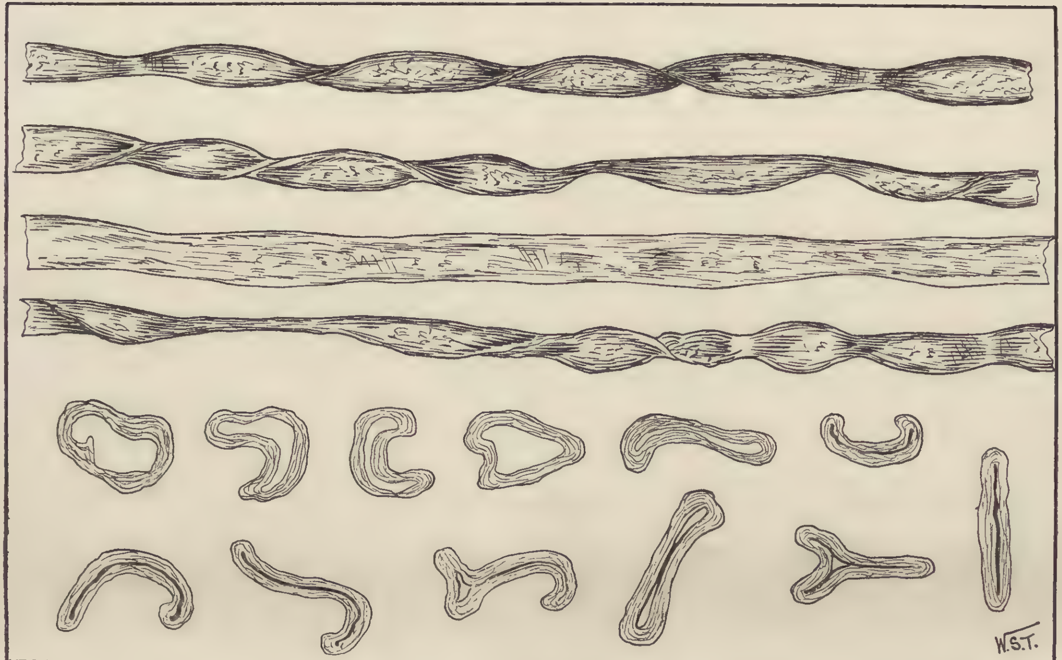


Fig. 2.

through the finishing scutcher or card; such a list would be of immense practical use in the setting of the card, draw-frames, fly-frames, and spinning machines, but its compilation would have to be undertaken by a very experienced and trained observer.

The cotton fibre, apart from its fineness and length, when examined under the microscope, is found to possess a characteristic which gives to it its principal value in the use to which it is put in the formation of yarns. This important feature consists of a long series of spiral twists extending the full length of the filament, and giving to it the necessary roughness to cause a resistance to being pulled asunder when, in combination with other fibres, it is twisted together in a thread. A rough idea of this appearance is given in the sketch, Fig. 2.

It is strange that most writers, in speaking of this peculiarity, convey the idea that the twists are comparatively few in number. One writer (Monie) even goes so far as to speak of a "collapsed cylindric tube twisted several times throughout its length." This is decidedly misleading, as an Egyptian fibre has about 250 twists in its length; or an average for several years of about 180 twists to the inch, and it is most probably owing to the variation in the number of these twists brought about by varying conditions of climate, cultivation, and carefulness in picking at the right time that the quality of the cotton depends; this leads us up to the point, when it will be an advantage and distinctly interesting to give what is probably the first explanation ever given of the cause of the twist in the cotton fibre and similar cell structures in the vegetable kingdom. The fibres, when forming, and being built up as an elongated cell from the seeds outwards, are hollow and cylindrical in section having very thin walls; a circulation

of the fluid necessary for life and growth is continually going on; and as addition is made to the length, we find that the thickness of the tube is gradually increased. The increments, of course, vary according to the conditions of growth, and leave the cylinder walls very unequal in thickness, longitudinally as well as circumferentially, but they are still, generally speaking, round. When maturity is reached, the circulation ceases, and the fluid interior is withdrawn by the seed, or disappears in some other way, so that the tube gradually collapses through the pressure of the atmosphere, into a ribbon-like thread with thick rounded edges, and in doing so, yields in the weakest and most probably the thinnest parts, first at the outer end, and from here travels down to the seed along the line of least resistance. It almost follows from this statement that a more or less spiral twist would be the result, and we find it so, but we should also expect that a variety of distortions would be introduced, long twists, and short twists, and an absence of twists (these are all apparent under the microscope), but a stranger feature still is seen in a series of twists indiscriminately arranged, turning first one way, and then the other. Mr. Midgley, though ignorant of the cause of it, in speaking of this latter and hitherto unobserved peculiarity, before a Mill Managers' Association of Bolton, gave the result of an examination of an Egyptian fibre, to show both the irregularity of twist and also its variation in direction. The following sketch, Fig. 3, will illustrate the matter: the figures and the curves within which they are placed represent the number and direction of the twists, whilst the straight lines between are portions of the fibre devoid of twist—there was no kind of equality in the spirals, some being coarse pitched, and others fine.

There is an undoubted advantage in all this, the interlocking of the fibres being made more certain, and it may be added that the discovery gives us another reason why the cotton fibre is so valuable to us. At the same time it is strange, as Mr. Midgley remarks, that such an important feature should have been unnoticed, or at least unmentioned by specialists who have written books on the subjects.

Before leaving this particular part of our subject, it is imperative that some notice should be taken of a characteristic of the fibre which is perhaps more important to us than the feature of the natural twists just described.

FIG. 3.

Two reasons prompt this explanation. In the first place, because any information which leads us to realise more fully why the cotton fibre is so valuable, will have a strong tendency to make people try to utilise its value more fully; and secondly, it is a characteristic which has been practically unnoticed by technical writers; in fact the matter has been treated in such a manner that to a thoughtful mind the strength of the fibre has been almost destroyed in effect through their description rather than strengthened.

It has been previously stated that the cotton fibre is an elongated cell. Now, the formation of this cell is one of simple growth outwards from the seed, and as a consequence we have a fibre which is relatively strong

and offers considerable resistance to breakage, and when it does yield, it is a rupture pure and simple; but writers, copying a well-known author, who, however, professed his ignorance of the matter, have described the building-up of this cell quite differently; it is said to be formed by the continual addition of small cells, one on the top of the other, until the whole length of the fibre is built up; when this happens, some action takes place that corrodes, or causes the separating walls of the various cells to disappear, and so an elongated cell is the result. If this explanation was true the cotton fibre would be worthless; every fibre would break up into its component cells at the gin, and yield a substance similar in appearance to flour instead of ginned cotton. There are many fibres in Nature found as above described, but their cells are so easily separated, no matter how well connected to each other, that they scarcely do more than hold themselves together. It is therefore important to emphasise the fact that it is the one long cell without break or division that gives the cotton fibre its strength, and renders it capable of standing operations the severity of which would be very destructive to weaker fibres. It can be bent, doubled up, and tied in knots without breaking: fibres built up of cells would be incapable of such treatment, and although attempts have been made to use them, their unusual weakness on this account has resulted in failure.

A deduction easily made from the explanation just given is that the twists are not the result of the fibre twisting or turning on its own axis, as erroneously stated by some writers; indeed, considering that all the fibres in the boll, both before bursting and just after, are intermingled in every imaginable manner, it is absolutely

impossible for them to turn even once on their own axis. From this consideration alone, but with an explanation of the phenomenon to help him, the reader will have no difficulty in understanding what has been said. An experiment that can be made by any one who wishes to test the matter may be performed by obtaining a thin tube of lead or other soft material. Scrape the walls thinner either spirally or in some irregular manner. If one end is plugged, and the air exhausted by a pump, the tube will collapse, and the thin portions will yield first. When, by scraping, a reduction in the thickness of the wall has been made in a spiral form, the tube will simply yield along the spiral, and no turning of any kind will take place on the axis of the tube, although the result would seem to suggest it, if no explanation was given as to the cause. India-rubber tubing will do as well for trying the experiment, but there is considerable difficulty in obtaining it sufficiently irregular in thickness to give good results.

The fibre is practically uniform in diameter throughout its whole length, and is not, as sometimes supposed, of a tapering character, about $\frac{1}{100}$ part of an inch at the top is quite round, brittle, and solid, and brings the fibre to an abrupt point, but very few of these points are found on the cotton after it has passed through the preparing machines.

The composition of the fibre is important, perhaps all-important from a dyer's point of view, but to the spinner the knowledge is essential, as it very materially affects the conditions under which it is made into yarn.

An analysis of cotton fibre from twelve different varieties made by Messrs. Davis, Dreyfus, and Holland, gave the following results :—

	Per cent.		
Carbonate of potassium	32·22	soluble in	water.
Chloride „	10·21	„	„
Sulphate „	13·02	„	„
Carbonate of sodium	3·35	„	„
Phosphate of magnesium	8·73	insoluble	„
Carbonate „	7·81	„	„
„ calcium	20·26	„	„
Peroxide of iron	3·40	„	„

The samples experimented upon were taken direct from the bale, but in an analysis made by Dr. Use the sample had been carded, and so he obtained a slightly different result from the above, since adhering mineral matter, etc., would have been cleansed from it by the opening, scutching, and carding processes.

The fibre, as we have already remarked, is an elongated cell, whose walls are almost entirely pure cellulose, 85 per cent of it being this substance. Surrounding the wall is an oily substance of a waxy nature, for the preservation of which so much is done in the mill by carefully maintaining the temperature and humidity and in the setting of the machines. It is of a very delicate character, and consequently easily damaged; in fact it can be rubbed off in a warm room where it becomes softened—this softening makes the fibre pliable and elastic. The interior of the walls is lined with remarkably fine fibrous strings, whilst the tube itself contains a substance resembling that seen in the quill of a feather.

When the cotton is picked, all the fibres are not perfect, numbers are immature and faulty from many causes—these latter are readily distinguished by the absence of twists, being simply flat ribbons and almost transparent.

Experiments made upon the individual fibre give results

that are tabulated below, and are interesting as showing the relative strength of different varieties :—

MEAN BREAKING WEIGHT OF A FIBRE OF COTTON IN GRAINS

Name.	O'Neill.	Monie.
Sea Island Edisto . .	83·9	—
Sea Island	—	100
Queensland	147·6	—
Egyptian	127·2	—
Gallini	—	125
Egyptian Brown . . .	—	150
Egyptian White . . .	—	146
Maranham	107·1	—
Pernambuco	140·2	160
Benguela	100·6	—
Orleans	147·7	140
Uplands	104·5	—
Texas	—	145
Mobile	—	110
Hingunghat	—	150
Dhollerah	141·9	—
Comptah	163·7	—

As it stands, however, it is very deceptive, and has led to many erroneous conclusions. The strength of yarns is almost in inverse order to the strength of the individual fibres. We frequently hear about a loss of a certain percentage of strength in the various processes which must always be accepted with considerable reserve; two people testing the strength of the same cotton could scarcely get within 10 per cent of each other in their results, and very large numbers of tests would be necessary even for this, so delicate and variable are the fibres.

In using the table for the calculated strength of spun

yarns, and comparing this result with the actual strength given on the testing machine, is a reprehensible practice, and can only lead to the fixing of false ideas on the subject in the minds of the readers; loss in strength through the presence of immature and over-ripe fibres, distortion of the fibres when in the aggregate as yarn, and the absolute impossibility of obtaining equality of tension in each fibre, are factors inherent in all yarns, and cannot be obliterated; they alone represent a large loss in strength in any test, and consequently it is scarcely correct to speak of the theoretical strength of yarn.

The cultivation of the cotton is a phase of the subject to which we will now devote a little attention. Other writers have devoted considerable space to descriptions of it, and reference should be made to their books. For our purpose a few brief remarks will suffice. In its native condition the cotton plant grows under the ordinary conditions of the surrounding vegetation of its home; suitable soil and climate are absolutely essential in order that it may exist. But it is a remarkable fact how plants or any living organism will continue to exist by adapting itself to its surroundings, provided any change that takes place is a gradual one, and the possibility of improving any plant from some special point of view, such as better flowers, better fruit, improved foliage, or increased wood, is almost unlimited. The indigenous cotton plants were practically uncultivated, and the rather poor character of many of the fibres, together with demand for an improvement in this respect, was taken advantage of in the direction suggested by analysis and analogy. By cultivation, and the application of fertilisers of a character likely to build up the plant, we have obtained a greatly improved fibre. Of course the methods of cultivation will vary considerably in different parts of the world,

according to the extent of Nature's own share in work. In a dry atmosphere and little rain, water must be introduced by some system of irrigation. If the soil lacks some portion of a substance necessary for good fibres it must be supplied. Time and seasons must also be chosen with regard to the climate and its variation, and a number of other points have to receive very careful attention.

The following table is compiled in order to give a general idea of the times of sowing and picking of most of the commercial cottons :—

Name.	Sowing.	Picking.
Sea Islands	1st April to 1st May	25th Aug. to 10th Dec.
Egyptian	March and April	September to December
Brazilian	15th Dec. to 1st June	July to February
Georgia	10th April to 1st May	15th Aug. to 1st Dec.
Florida	1st April to 1st May	10th Aug. to 1st Dec.
Mississippi	5th April to 10th May	10th Aug. to 15th Dec.
Louisiana	1st April to 10th May	1st August to 15th Dec.
Alabama	5th April to 10th May	10th Aug. to 15th Dec.
Texas	15th March to 10th May	1st Aug. to 20th Dec.
Arkansas	15th April to 15th May	15th Aug. to 15th Jan.
Tennessee	15th April to 15th May	1st Sept. to 15th Jan.
Bengal	June	October to January
Oomrawutte	June	November to January
Broach	June	January to April
Dhollerah	June	February to April
Coompta	August	March to May
Dharwar	August	March to May
Tinnevelly	October to November	February to April
Madras (West)	August to September	March to June
Hingunghat	June	November to March

In the preparation of the ground for planting, fertilisers are first plentifully ploughed in, after which ridges are formed with spaces of 5 or 6 feet between them, and upon the top of these the seeds are sown in holes, a few in each hole, or in a dribble or groove when the seeds are sown

along the full length of the ridge. When the plants appear above the ground they are thinned out, the strongest ones being left a little longer; another thinning takes place shortly after, leaving only the strongest plants growing at suitable intervals along the ridge. The wide space between the ridges permits a plough to pass between to bank up the ridges around the plants as they develop, and in addition constant attention is required in hoeing to keep the soil free from weeds. During growth the plants are subject to be attacked by insects of various kinds. These, by laying their eggs on the leaves, branches, and in the flower and boll, introduce a deadly enemy to the plants, for subsequently, as caterpillars, they do immense damage to the crops. Immediately following the disappearance of the flower, which lasts only a day or so, the fibres are built up from their surface. Directly the seed-case bursts, the boll of cotton is plucked away, and after a sufficient quantity has been gathered, it is carted to the ginning factory, and there treated for the separation of the fibres from the seeds.

CHAPTER II

COTTON GINS

In ginning we have a process, directly connected with the cotton industry, which has received but scant notice at the hands of writers who have made textile machinery a speciality. This is partly accounted for by the fact that the operation is not performed within the four walls of our own cotton-mills; therefore only an indirect interest is

presumed to exist. But when, in the subsequent processes, difficulties arise and defects are discovered that have their origin in bad ginning, it is absolutely necessary that an intelligent knowledge of the process should be obtained, in order (if for no other reason) that when evils do appear suggestive of bad ginning, the cause may be sought for in the right direction. Also, since ginning is purely a mechanical operation, involving a large amount of ingenuity and design, it is only natural that an interest should exist, which demands to know something of the details of its action and the principles underlying its operations. It is to supply the above requirements that a little more than a superficial attention is given to the subject, reliance being placed on the illustrations to give completeness to the written descriptions.

The primary object of ginning consists in separating the fibres from the seed, and a perfect operation would be performed if the separation was effected without the slightest injury to either. It is hopeless, however, to expect that this desirable condition will ever be attained. So many varying factors enter into the process through inequalities that exist in the fibres surrounding the seeds, and in the seeds themselves, that the degree of success of the operation can only be judged upon the basis of its average result. We shall always find some fibres will break in two or more pieces before they will separate at their connection with the seed; other fibres will bring away, in the separation, portions of the thin husk of the seed; while a certain proportion will always be completely ruined by being torn, broken, or scraped. With the utmost care, broken seeds seem to be a necessary evil, and neps can be so easily formed in the process that these and many other defects inherent in the material or machine prevent us hoping for any great

improvement upon our present methods of dealing with the problem.

Previous to the introduction of modern machinery ginning was performed by hand, or by machines of a very primitive character—such as the "Foot Roller," and its improvement the "Churka." As the cotton industry developed, greater production than these were capable of was necessary, and machines driven by power were introduced. It is through these machines that the greater part of our supply of the raw cotton has to pass before it reaches our hands.

Numerous forms of gins have been tried, but at the present time only three are used to any large extent—viz. the "Knife Roller" Gin, the "Macarthy" Gin, and the "Saw" Gin. A description of each will be given in their order.

We select for our first example

The "Knife Roller" Gin

This is shown in section and plan in Fig. 4. The seed cotton is placed in bulk on the table X, and pushed forward down the hopper-shaped receptacle, where it comes into contact with a knife roller B, formed of a number of knife discs, the knife portion being arranged in such a manner that anything coming into contact with it is given a reciprocal or to-and-fro motion, as well as being subject to a striking action due to its revolution. The seed cotton is carried forward in the direction of B's motion until it is brought into touch with a leather roller A. This roller, which has a very roughened surface, due to spirally-formed saw cuts, has pressing against it by means of springs F a steel doctor knife D. The cotton fibres brought into con-

tact with the leather adhere to it, and are carried round past the knife. It is impossible for the seeds to follow, so if the fibres by this action are not wrenched from them the seeds will remain at the point of contact of the doctor knife and leather roller, with the fibres still connected with it. The essential feature of this gin now comes into play. The knife roller B is so set as to act upon these adhering seeds, and it gives to them a gentle to-and-fro motion, repeated very quickly, and at the same time a slight striking action or pressure, also repeated quickly. The combined actions soon cause the seeds to separate from the fibres and to fall down through the grid H to the floor. The freed fibre passing forward is stripped from the roller by some arrangement of stripping board similar to that shown at Y. A better idea of the action just described may be obtained on reference to Figs. 5 and 6, where the angular knife edge is shown in two positions, and its action on the seeds in moving from one position to the other is easily traced. The next knife on the circumference of the roller would then act upon the seeds and move them back to their original position, this being repeated until the desired result is obtained. The cotton is stripped, as a rule, in a fairly continuous fleece (though this depends largely on the feeding), and in a very flossy condition—a condition that, if transferred to our cotton-mills, would dispense with much elaborate and expensive opening machinery at present used, and reduce the cost of production in that department considerably.

The sketch, Fig. 4, shows the double-action form of this gin. It is so arranged, without interfering with the part already described, that the seed cotton not taken up by one leather roller A is brought round into contact with the other roller A (on the right of the drawing), where the

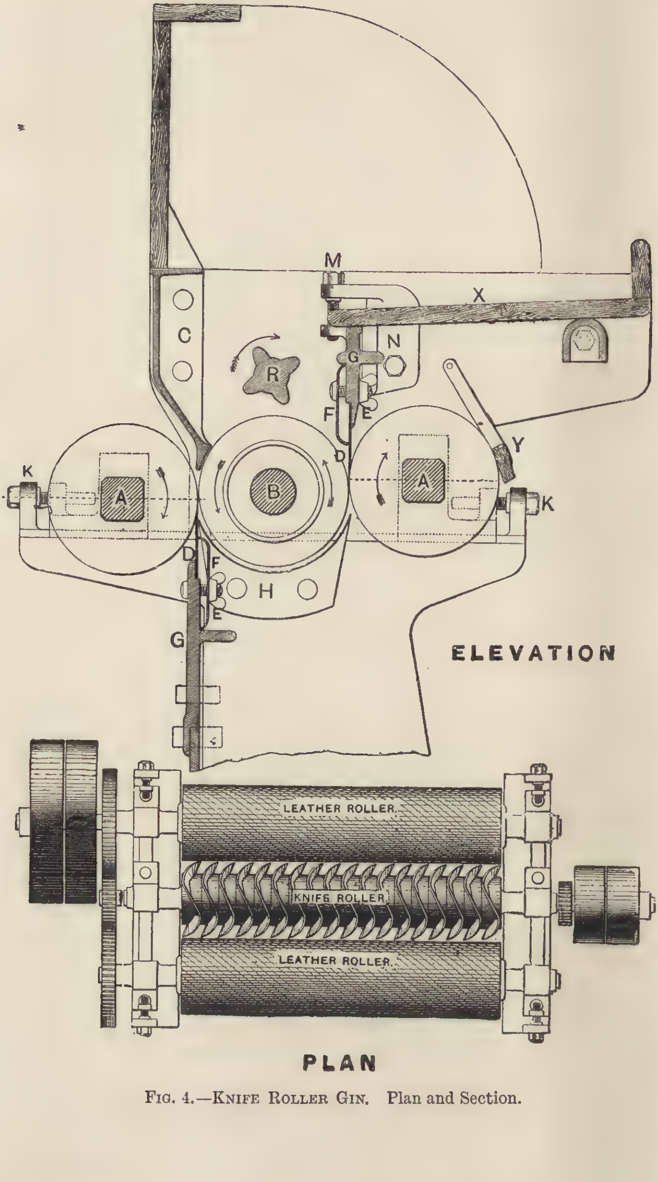


FIG. 4.—KNIFE ROLLER GIN. Plan and Section.

same process as described above is gone through, and to which the same letters equally apply. This results in a greatly increased production, as well as in economy in the power required for driving and the space occupied. A

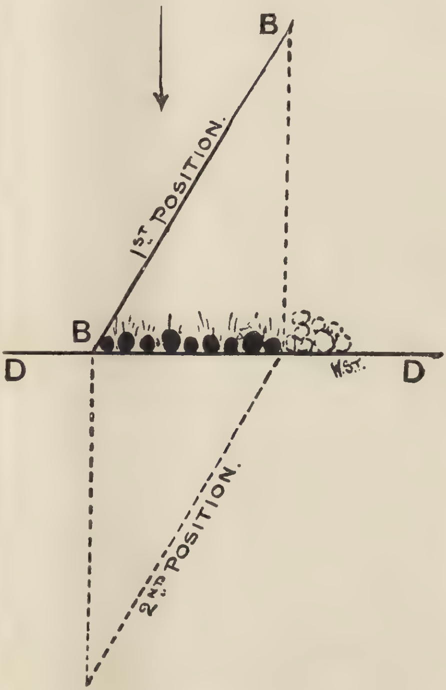


FIG. 5.

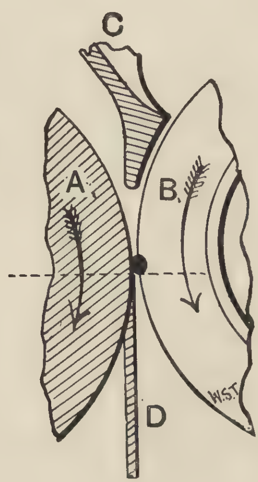


FIG. 6.

close examination of the drawing will enable one to understand the care and judgment that is necessary in setting the gin for any one class of cotton. The relation of the dish rail C to the knife roller must be such that seeds cannot get between them. Carelessness here produces

large quantities of crushed seeds, and yet if too near the fibres are severely damaged by rubbing. The doctor knife must occupy such a position that its sharp edge does not cut the fibres as they are carried past it. This is prevented by always setting the edge of the knife on the centre line of the leather roller, or very slightly on one side of this line, in the direction the roller is revolving. In this position it holds the fibres firmly at the end where they are connected with the seed, thus enabling the doctor knife to effect a separation at this point. The degree of pressure of the doctor knife upon the leather roller can be varied at will by means of the springs F and thumb-screws E, the pressure depending principally upon the tenacity with which the fibres adhere to the seeds.

The position of the leather roller in relation to the knife roller is another very important matter; for, in addition to the necessity of being perfectly parallel with each other, they must be set apart such a distance as to equal about one-third the diameter of the largest seed. If set too near, the seeds would be broken, while if too far away large numbers would not be acted upon by the knives, and the machine would block itself by an accumulation of unstripped seeds. The setting arrangements for the above conditions are shown in the sketch, their manipulation being of such a simple character that good results are easily obtained.

An auxiliary roller R, as shown, has recently been added to the machine, and has been found very effective in breaking up the large clusters of seed cotton which are fed to it, and also in maintaining in a favourable condition a constant supply of cotton to the knife roller.

The production of this machine varies from 100 to 120 lbs. of clean cotton per hour, and it may be as well to

state here that the proportion the clean cotton bears to the seed cotton is, on an average, about 1 to 3. For every pound of lint or clean cotton there will be 2 lbs. of seeds. Of course this proportion varies, most Indian cottons being as $4\frac{1}{2}$ to 1.

The speeds for good working are :—

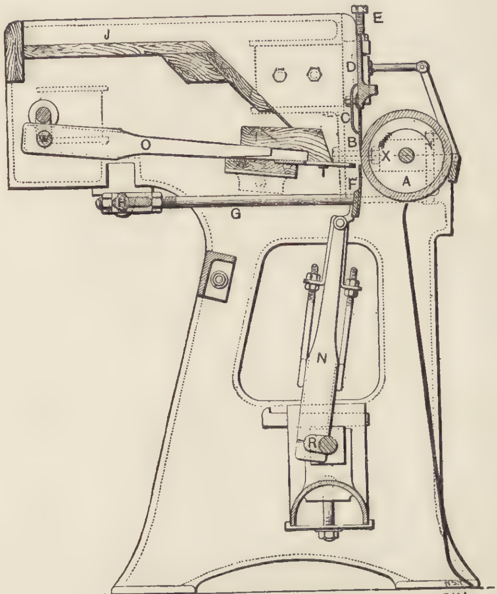
Knife roller . .	250 to 300 revs. per min.
Leather roller . .	120 to 150 „ „

The power required to drive is a little over 2 i. h. p.

The "Macarthy" Gin

The Macarthy Gin is a form of machine that differs in several important features from the knife roller gin. A section is shown in Fig. 7, which we will proceed at once to describe. The cotton is fed on to the table J and, falling into the hopper, is brought into contact with the revolving leather-covered roller A by means of the reciprocating action of a feeder bar O, this bar O being operated by the crank W. The leather roller has pressing against it, by means of springs C, a doctor knife B, which fulfils a purpose similar to that mentioned in the description on the "Knife Roller Gin." The remarks there made as to its position in relation to the centre line of leather roller are equally applicable to this machine. As the roller A revolves in the direction shown by the arrow, its rough leather surface carries the fibres past the doctor knife. The quickness of this action, through the seeds following and being suddenly checked by the knife, may cause a few fibres to separate, but the greater portion of the seeds remain at the knife edge, with the fibres still adhering to them. They are removed by an operation which differs greatly from the

means used in the knife roller gin. A steel beater blade F is connected, by means of a connecting-rod N, with a crank R on the driving shaft; it is also fixed to a rod or bar G, which is centred at H, the seeds being acted upon by the rapid reciprocating motion given to the beater blade by



SECTION OF SINGLE MACARTHY COTTON GIN

Fig. 7.

the crank. The repeated blows they receive soon detach them from the fibres, which are carried forward, the seeds meanwhile falling on the grid T, through which they pass into a suitable receptacle. It will be observed that F is guided in its path—which is a portion of a circle, having H as centre—through its connection with the bar G. This

bar is also used to adjust the distance of the blade from the leather roller, according to the size of the seeds. For this purpose the ends are screwed, and fitted with adjusting nuts, which also lock it in position when once it is set correctly.

The ginned cotton is stripped from the roller by the stripping board shown in sketch. It falls to the ground in a fairly continuous fleece, and is kept from mixing with the seeds by means of a sheet-iron division plate.

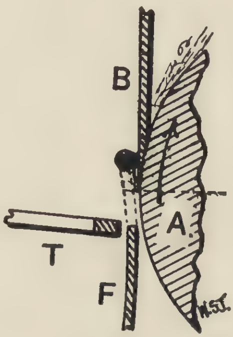


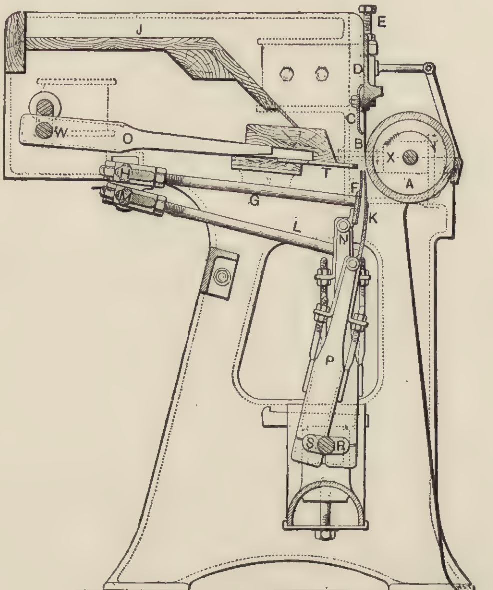
FIG. 8.

An enlarged view of the principal features of the gin is given in Fig. 8, and the remarks that follow may be better understood by a reference to it. It is complained of this machine that a large number of neps are formed, and the reason is not far to seek. It must be remembered that the fibres do not pass the doctor knife singly, but generally a number at a time, the fibres belonging to one, two, or more seeds going through in one place. The blade F, in rising up to about $\frac{3}{8}$ of an inch above the edge of the doctor knife, either knocks the seeds away or takes them with it. As the seeds receive repeated blows

before the separation is effected, it follows that this latter action is generally the one performed by the beater blade, so that the seeds not detached are compelled to follow the blade, and naturally drag back the fibres attached to them, which have passed under the doctor knife. This movement of the fibres, it will be noticed, is in opposition to the revolution of the leather roller, whose rough surface is going at the rate of about 200 ft. per minute. This going forward and drawing back process is bound to result in the fibres mixing themselves up and getting into those small entanglements that cause so much trouble and inconvenience in subsequent processes. The dragging back of the fibres over the sharp edge of the knife is also a source of mischief which is undoubtedly a cause to which may be traced many defects that ultimately appear in the form of mutilated fibres. A double form of this gin is given in Fig. 9. There are two beater blades F and K, actuated from cranks R and S. They rise and fall alternately. A larger production is by this means obtained with a lower speed of driving shaft, another advantage being the reduction of the vibration, which, in a single machine, is a serious evil, the two cranks in the double form tending to balance each other. A close study of the action of the two beater blades F and K will show that the evil mentioned in connection with the single gin is aggravated in this form; for it is possible for small seeds to be on the edge of the knife without being acted upon by the blade F, so that the larger seeds that F takes up will withdraw their fibres, not only in opposition to the surface of the roller, but also in opposition to the fibres adhering to the smaller seeds, this, of course, intensifying the probability of entanglement occurring.

The leather rollers are generally made of solid leather

washers, with a hole through the centre of each to slide upon a strong square iron shaft, upon which they are firmly fastened, the diameter of the washers, when first made, being about 7 in. The roller wears very unevenly, so it is necessary to keep it constantly trued, or the doctor knife



SECTION OF DOUBLE MACARTHY COTTON GIN

FIG. 9.

will not press equally the whole length. The edge of this knife also occasionally requires grinding, to keep its edge sharp and true.

	Production. Lb. per hr.	Power. i.h.p.	Speeds. Crank-shaft.	Speeds. Leather roller.	Driving pulley.
Single Macarthy...	30	1	800	150	6½ in. by 3 in.
Double ,, ...	45	1¼	550	150	6½ ,, by 3 ,,

The "Saw" Gin

In this gin we have a machine whose characteristics have nothing in common with the two types previously

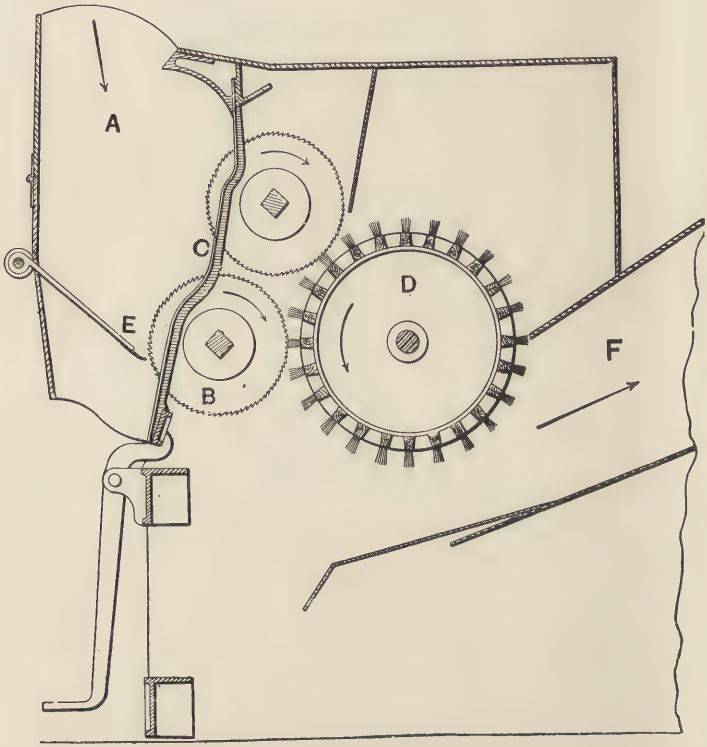


Fig. 10.

described—the method of procedure is so entirely different. A section through the principal part of the machine is given at Fig. 10. Its essential feature consists of a series of

quickly revolving saws BB, which are threaded on a square shaft, a space of about $\frac{3}{4}$ of an inch being left between each saw. This space is almost filled by an equal series of bars C, the arrangement of saws and bars being clearly shown in Fig. 11. As the cotton is fed into the hopper A, it comes into contact with the saws, whose sharp teeth instantly carry it forward. It is impossible for the seeds to follow, so the fibres are simply wrenched from them and are carried round until they are stripped by the brush D. The fibres are then sent along the passage F under the combined influence of centrifugal action and a powerful draught acting through perforated plates or cages; from here it is generally passed through a condenser and delivered in the form of a sheet. The seeds when stripped of their fibres fall down through the grid E. The sketch shows an arrangement for moving the bars bodily away, so that the saws can the more readily be attended to when necessity arises.

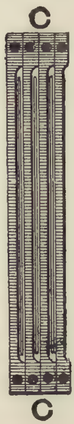


Fig. 11.

It is easy to see that this gin has very serious faults. The rough treatment the fibres receive naturally results in innumerable breakages and neps. The machine is extensively used in America for the lower kinds of cotton, but for the better classes and Sea Island it is totally unsuitable.

CHAPTER III

BALE BREAKERS

HAVING described the process of ginning, it will be as well at this point to give a slight description of an operation through which the cotton goes before being shipped to the country for which it is destined.

We have seen that the cotton as it comes from the gin is in a very loose, fleecy condition, and if it were transferred in this state to a mill near at hand no opening process would be necessary. But since the great bulk of cotton grown has to be carried considerable distances, it is absolutely necessary to adopt some convenient form of packing it into as small a compass as possible. This packing or baling process used to be, and in some places still is, performed by screw or steam presses. Hydraulic presses are, however, generally used at the present time, and by their means an enormous pressure can be exerted in compressing a large amount of cotton into a comparatively small and compact bale. The making of the bale is not by any means an instantaneous operation; it is, rather, a gradual one. For instance, a certain amount of loose cotton is placed in a receptacle, and the hydraulic ram compresses it into a thin layer; upon this is placed another lot of loose cotton, and the two lots are now compressed together, with the result that there will be two layers almost distinct from each other. This feeding of the loose cotton to the press goes on until the whole bale is built up to the required size in a series of layers. It is sometimes asked if the great pressure put upon the bale—

amounting sometimes to almost 3000 tons—has not a damaging effect upon the fibre. This may be answered almost decidedly in the negative. In the first place the microscope has not yet been able to discover any difference between the fibre from the pod and from the bale. Again, it is practically impossible for any fibre to get crushed or even compressed to an infinitesimal proportion of itself in the baling process; a few fibres in a layer, if submitted to a great pressure, would easily be crushed, but when in the press we have many thousands of fibres superimposed upon each other, the probability of any distortion in their cross section is reduced to a very small quantity.

It will be interesting to give some idea of the size and weight of the bales, but as they are constantly varying, we extract a portion of the United States Consular Report, which, it will be seen, contains in a concise form much information of a valuable nature.

American bales of cotton received at Liverpool weigh from 290 to 878 lb., and measure from 4 ft. 6 in. by 3 ft. 4 in. by 2 ft. 3 in. to 6 ft. 6 in. by 3 ft. by 2 ft. Egyptian bales weigh from 672 to 840 lb., and measure about 4 ft. 3 in. by 2 ft. 7 in. by 1 ft. 10 in., say 20 cubic feet. East Indian bales weigh as follows:—Surat, from 346 to 431 lb.; Madras, from 460 to 486 lb.; Tinnivelly, from 499 to 531 lb., and measure about 4 ft. 1 in. by 1 ft. 10 in. by 1 ft. 4 in. say about 9 cubic feet. Brazilian pressed bales weigh from 367 to 428 lb., and measure about 4 ft. 1 in. by 1 ft. 10 in. by 1 ft. 5 in.; unpressed weigh from 100 to 419 lb., and measure from 2 ft. 10 in. by 2 ft. 9 in. by 1 ft. 4 in. to 5 ft. 6 in. by 2 ft. 6 in. by 1 ft. 3 in. Peruvian bales weigh from 109 to 504 lb., and measure from 2 ft. 6 in. by 2 ft. 1 in. by 1 ft. 8 in. to 5 ft. 6 in. by 3 ft. 4 in. by 2 ft. 10 in.

American bales are generally covered with a coarse loosely woven bagging, easily torn, and quite incapable of bearing the handling they are subjected to in transit. Generally speaking, the bales are bound by seven iron-hoop bands, each band being fastened by an iron tie or buckle; the bands with ties vary in weight from 10 bands = 12 lb. to 10 bands = 24 lb. Cotton from the other countries named is covered with closely woven, strong, but not heavy, canvas, and, with the exception of cotton from South America, is bound with iron bands. South American cotton is bound chiefly with twigs or ropes, but in some parts of Brazil and Peru the bales are bound together by iron wire or bands. Egyptian bales have about 11 bands, 10 bands = 16 to 18 lb. East Indian bales are bound by 3 bands, sometimes of equal length, each length passing three times round the bale, by one long and two short, and sometimes by one short and two long bands, the total turns round the bale being about the same in each case. The weight of the bands runs from 2 to 4 lb. per bale. On pressed Brazilian bales there are 10 bands = 33 lb., and there are two on each bale. On unpressed Brazilian bales the binding is very irregular, but the weights run as follows:—Bands, 10 = 16 lb.; twigs, 10 = 16 lb.; wires, 10 = 3 lb.; ropes, 10 = 4 lb. Peruvian bales are bound by three to four wires, or three bands, and some heavy bales have six wires. Light wire, 10 = 3 lb.; heavy wire, 10 = 12 lb.; bands, 10 = 3 lb. Covers weigh from 5 to 14 lb., according to size of bale. (Accompanying this report were specimens of some of the various materials used to cover the cotton from the several countries named, some of that from the United States had an appearance more resembling a net than canvas.)

Owing to the nature of the bagging described above, most American bales are landed in a very ragged condition, with the cotton much exposed, and either because of the poor material of the iron bands, and especially the ties, or because of the extremely rough treatment on the railways or steamships, great numbers of bales are landed with several bands missing. In consequence of the pressure of the bands being removed, the bales have expanded and burst the covering, the cotton in the loose part of the bale merely holding together by its own tenacity. Sometimes bales are completely broken up, and are landed in bulk. Unless the bales have been lying in wet or mud before having been shipped on the railways or steamships, and have become what is known to the trade as "country damaged," the quality of the article does not deteriorate. Cotton from the other countries mentioned is landed in excellent condition, with, perhaps, the exception of unpressed cotton from Brazil, which is not in good condition.

American cotton, owing to the serious defects in packing mentioned, suffers seriously as compared with cotton from other countries because of the great loss which is caused by many bales being landed in a torn, loose, unbound condition; not a loss caused by deterioration of the quality of the contents, but a loss in weight, a loss in cost of making the bales merchantable; a loss owing to the difficulty of identifying the bales, many of them having marks torn away, and the cost of apportioning them among the claimants amounts to a considerable sum; a loss when cotton is landed in bad weather by its gathering dirt and absorbing moisture; and, of late, a loss owing to the imposition by the fire-insurance offices of a very heavy discriminating tariff against cotton as compared with other

goods, solely on account of the heavy losses by fire of American cotton, it being alleged that the meshy nature of the canvas used and the ragged condition of the bales when landed and warehoused in Liverpool render American cotton peculiarly liable to take fire.

Much of the bad condition in which American cotton is landed is due to the practice of packing it in bales of irregular sizes, many of which stevedores at the American ports reduce in length by cutting off the ends to facilitate stowing. These stevedores also cause much damage by screwing the bales in the ship's hold, by which process the covering is torn, and such a degree of tightness is attained that many bales have to be torn out on this side by steam power, causing further serious damage to the covering. This practice of screwing seems to be confined to vessels loading in the United States ports.

There is a growing practice in America, it is stated, of putting bagging on bales, not for protective purposes, but simply to make weight; on many bales there are numerous folds of bagging at the ends, where they serve no useful purpose.

When the bale is opened in our cotton mills these layers, which exist as comparatively hard matted cakes, prove the necessity of something being done that will lessen the tendency of a very rough and damaging operation in the opening process. Up to within the last few years manual labour was employed for this purpose, and in some of the older mills hands are still used for breaking the cotton. It may, however, be taken for granted that the operation has now developed into purely a mechanical one for all kinds of cotton, the machines used for the purpose being known as "Bale Breakers." Several kinds of these machines are made, and in order to thoroughly

understand their action, sections are given, which show their principal features perhaps better, even, than a written description.

In Fig. 12 we have the well-known type of bale breaker with four lines of rollers. The cotton is fed upon a lattice, which carries it forward in the direction of the arrow. It passes through the machine by means of four pairs of suitably formed rollers, and emerges in a condition for the

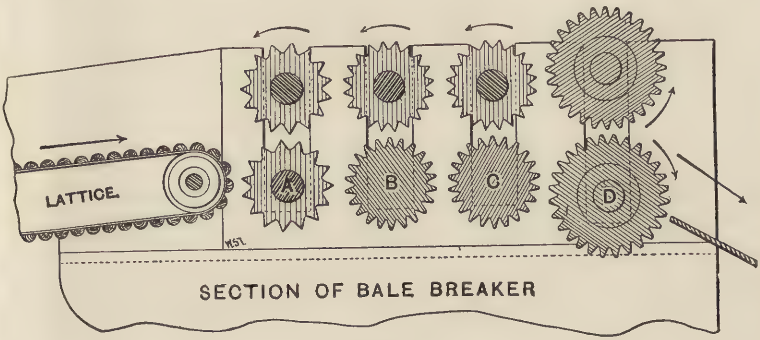


FIG. 12.

next process superior to that in which it came from the bale. In view of the importance that is attached to bale-breakers, it will be of advantage to follow the cotton through the machine, and note carefully the treatment it receives. It will be noticed that the first pair of rollers A, which take the cotton from the lattice, are coarse spiked ones, and about 6 inches diameter, made in sections, so that if breakages occur they can readily be repaired without sacrificing the whole roller.

It must be understood that the bale breaker is by no means a delicate machine. The hard, thick slabs of cotton necessitate a machine that is capable of withstanding the

severe strains and sudden shocks which such conditions set up. In consequence of this we find machines of this type strongly built, and yet arranged so that if a breakage does occur it can be easily mended. The effect of passing the cotton between these spiked rollers is to get it thoroughly penetrated from both sides by a series of holes. This is very important to notice, for though the thick layers may look the same after the penetration, yet they are in such a condition that very little effort would be required to break them up.

This penetrating process is continued by the next two pairs of rollers B and C, a slight difference, however, being introduced into their construction. The top rollers are spiked and of a fine pitch, while the bottom rollers are fluted their full length. The reason for this is easy to understand. In order to pull the slabs of cotton in pieces, the speeds of B, C, D are accelerated, so that a draft exists between each pair. This means that B not only takes the cotton from A, but that it takes it forward quicker than A can deliver it, which naturally reduces the slab in bulk. This drawing process is performed by each of the last three pairs of rollers. The fluted rollers are consequently introduced in order to give the rollers a better holding power, and in the middle two top rollers the fine pitched spikes continue the penetrating process.

The whole machine, as a rule, has a draft of about 32. This special draft is subject to variation, and in some machines is very much lower; a large draft is, however, preferable. When the draft is the one mentioned it is distributed through the machine as follows :—Between the first and second is about $2\frac{1}{4}$; between the second and third it is about $2\frac{3}{4}$; so that the greatest draft exists

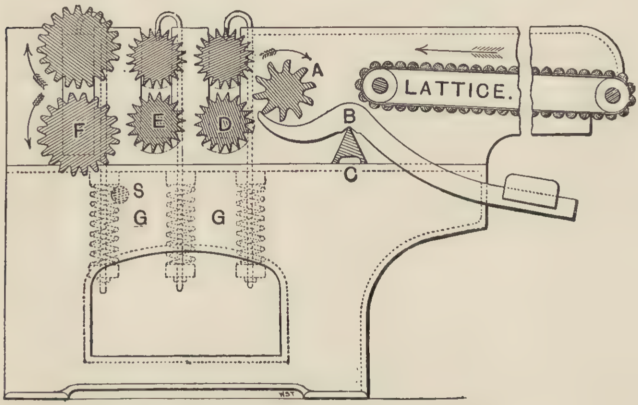
between the third and fourth, which equals about $5\frac{1}{4}$. This big draft accounts for the fact of the last pair of rollers (8 in. diameter) being fluted.

It will be observed that only lumps of cotton over 6 in. wide can be actually pulled into smaller pieces; but this does not interfere with the efficacy of the machine in bringing the whole mass of cotton into a condition extremely well adapted for the further opening process.

All classes of cotton can be successfully worked by this machine, from fair American upwards, and it is capable of an output up to 80,000 lbs. a week.

Pedal Bale Breaker

Fig. 13 shows a section through this machine. Its

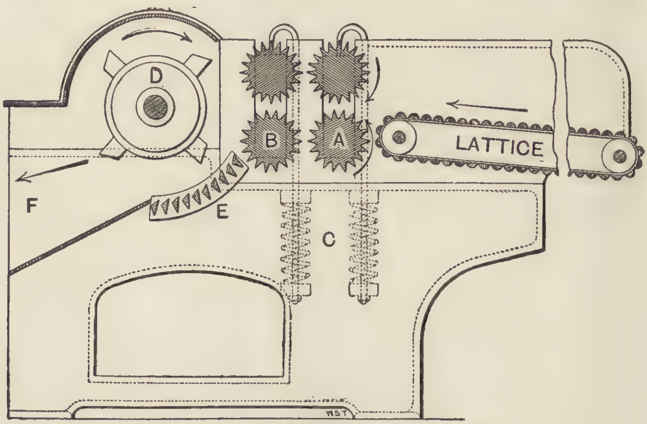


SECTION OF PEDAL BALE BREAKER.

Fig. 13.

variation from the previous one consists of substituting

for the first pair of rollers, one roller A working over a series of pedals or weighted levers B, having their fulcrum at C. It is an important alteration, for by this means the grip of the cotton is brought much closer to the roller D; consequently smaller pieces of hard cotton can be drawn or pulled partially or completely asunder. Another advantage it possesses lies in the fact that both thick and thin pieces receive their share of the pulling action of the roller D, the



SECTION OF PORCUPINE BALE BREAKER.

Fig. 14.

pedals, of course, yielding so as to permit of this. The three lines of rollers are all speeded to produce a draft. For instance, the draft between the pedal roller A and the first pairs of rollers D is about $2\frac{1}{4}$; between the first and second it is about $2\frac{1}{2}$; while between the second and third it reaches about $4\frac{1}{2}$. Their action upon the cotton is similar to that described when dealing with Fig. 9. All the classes of cotton from fair American to Sea Island can with advantage be passed through this form of machine.

"Porcupine" Bale Breaker

A machine for dealing with the poorer classes of cotton, like low American and Indian, is shown in section in Fig. 14. The cotton passes from a lattice through two pairs of spiked rollers A and B. As it emerges from B it is struck by a quickly-revolving small porcupine cylinder, which breaks the hard lumps of cotton very effectively, at the same time knocking certain impurities from it, which fall through the dust bars shown. The action of this cylinder is in no way a severe one, when it is remembered that the rollers are large in diameter (5 to 6 in.), and so nothing prevents the cotton from yielding instantly to the teeth of the cylinder as it revolves.

CHAPTER IV

COTTON MIXING

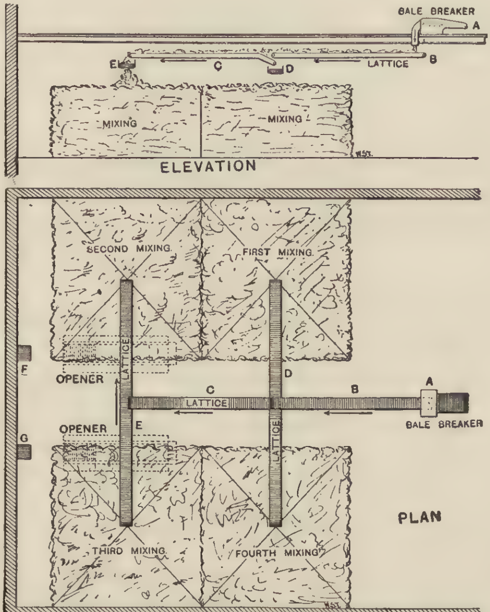
The cotton from the bale having been satisfactorily broken up, it is now ready for the mixing process. This operation is one that can scarcely be over-estimated in its importance on the ultimate result of the quality of the yarn spun. The reason for this is apparent when the following causes tend to interfere with and prevent uniformity of the yarn that is spun from even only one class of cotton. Cotton from the same district, or from fields adjoining each other, varies in quality through a difference in the character of the soil in which the plants grow. It also varies in quality according to the length of time the open boll has been exposed to the sun. The length of the staple is likewise

a variable quantity, as is also the colour of the cotton; though the colouring has a very slight range from a colourist's point of view, it has a rather wide one from a cotton-spinner's standpoint.

Again, the classification of cotton is a very irregular and unreliable one, so that a buyer has no guarantee that every bale is to sample. It will thus be seen that the object of mixing is to obtain as near as possible uniformity in length of staple, uniformity in quality of staple, and uniformity in colour. To attain even partial success in arriving at these results, it is absolutely necessary to have a wide experience and good judgment. Nothing, therefore, will be said here about the quantities or qualities of the mixed cotton, our object being to give a description of the mechanical means employed to carry out the mixing in as efficient and economical a manner as possible.

In order to give a clear idea of the operation, a diagram (Fig. 15) is shown. Cotton from one, two, or more different bales (a portion from each alternately, according to the mixture required) is passed through the bale breaker A. As it comes from the machine it falls down a short trunk upon a travelling lattice B, near to the ceiling in the room below. This lattice is one of a series B, C, D, E, which are so arranged that the cotton can be taken as required to any one of the four mixing stacks or bins shown in the plan. In the sketch the cotton is being taken along in the direction of the arrows by the lattices B and C. From C it falls on the cross lattice E, which, travelling in the direction of the arrow, carries it to the second mixing stack. Here it is spread about over a certain area—the larger the better. If any other mixing is required—for instance, the third—the lattice E is simply reversed in direction. When the first or fourth mixing is being made,

the lattice C is reversed in its movement, so that the cotton passing down between the juncture of B and C falls upon the lattice D. This lattice takes the cotton to whichever of the two mixings is required.



COTTON MIXING SHOWING ARRANGEMENT OF LATTICES

FIG. 15.

When the cotton comes to be removed from the stacks and passed on to the opener, a commencement is made at the top, and by working downwards to the floor for about a yard in width a greater chance of regularity of the mixing is obtained, for it enables a little of every layer in the stack to be passed through the opener in a short time. The openers in our illustration are shown dotted, being in

the room below. So in this case the cotton is put down the trunks F and G, which, passing through the floor, carry it direct to the hopper feeder, or place it within easy reach of the person feeding the openers.

From what has been said it can be seen that lattice arrangements may be made suitable for almost any conditions of mixings and relative positions of the rooms in which the operations take place. For instance, in the sketch, Fig. 12, the bale breaker A, instead of being in the room above, might be placed in the same room, or a room on the same level. If this were so, a vertical double lattice would convey the cotton from it up to the ceiling lattices, from whence it could be distributed in any direction. It is advisable when making a mixture to have it as large as possible, one that will last several weeks being preferable to one that is worked up within a short time; for if a large order for a certain quality of yarn is being executed, a decided risk is run, for the reason already given, in mixing only a small quantity at a time. In addition to this the cotton is all the better for standing in the stack a short time, as by this means the air can circulate through it and render it far softer and more supple than it would otherwise be.

The cotton being now in a condition ready for the opening and cleaning process, we are in a position to inquire into the principles that underlie this operation. To do this we must go back to the cotton fields, and there we shall find that fine sand is blown about in all directions over the cotton-growing districts. It enters the open bolls of cotton, and forms an impurity which it is necessary to remove. Again, in gathering the cotton the boll is plucked quickly (by young children as a rule) from the plant, and comparatively speaking large quantities of portions of the

dead leaves, stalks, and husks are taken away with it. In the ginning process, also, we have seen that a quantity of broken seeds, and their husks, are almost inevitable as a result of that operation. All these substances are foreign to the cotton, and render it practically useless to the manufacturer until they are removed. The trouble caused by their presence is moreover greatly intensified, as we have seen, by the unusual degree of compression the cotton undergoes for the purpose of transport.

This general idea of the condition of the cotton will serve to show us the necessity of opening and cleaning; and it will also enable us to understand more clearly the reason for the various mechanical methods used to get rid of the impurities, the motive underlying whatever means are adopted being that of isolating or separating as nearly as possible every individual fibre, so that the foreign matter will fall away, either freely or under the influence of centrifugal force. Taking into consideration the delicate nature of the individual fibre, we see the necessity of attaining the above results gradually. The bale breaker plays an important part in breaking-up and softening the hard cakes from the bale, but it leaves the cotton in very irregular masses, and when fed to an opening machine its distribution on the lattice, to any degree of regularity, would depend upon the care and judgment of an attendant. It is not surprising to find that this factor, as well as its accompanying expense, was the primary cause of the introduction of the hopper feeder—a machine which to a very large extent dispensed with both. It is not only on this account that the utility of the hopper feeder has been recognised, for improvements which have been made since its introduction have enabled it to act not only as a feeder and as a direct regulator, to a degree of fineness that would

be absolutely impossible with the best hand-feeding, but also to a certain extent as an opener, thus continuing the work of the bale breaker, and presenting the cotton to the opener in such a condition that the possibilities of damage to the fibre in passing through that machine are reduced to a minimum.

A typical section of the hopper feeder is shown in Fig. 16. At A we have the trunk connected with the mixing-room, and down which the cotton is thrown. Passing through the trunk in the direction of the arrow, it enters the chamber B, where a travelling horizontal lattice C carries it forward until it comes into contact with an almost vertically spiked travelling lattice D. The inclined spikes of this lattice enter the cotton, and carry it upwards past the evener roller E. The object of this roller is to prevent any superfluous cotton passing forward. This is effected by revolving the roller at a quick rate, so that a continuous series of blows are given by strips of iron fixed on its circumference. The striking edges of the strips are made with V-formed serrations, rounded top and bottom. The surplus cotton is by this means thrown back into the chamber B. The cotton, which is left evenly distributed on the spikes passing over the top, is next acted upon by a stripper roller F, which clears the cotton from the spikes of the lattice, and in doing so throws it against a series of grate-bars G, through which any loose dirt will fall. The cotton is now directed to the pedal roller H, and passes forward between it and a number of pedals K, which serve the purpose of regulating the amount of cotton delivered. For instance, if too much is going through, the pedals are depressed, and by their connection with a cone-drum driving arrangement cause the roller H to revolve at a slower rate. If too little is going through, the roller is

automatically speeded. We can now appreciate the ad-

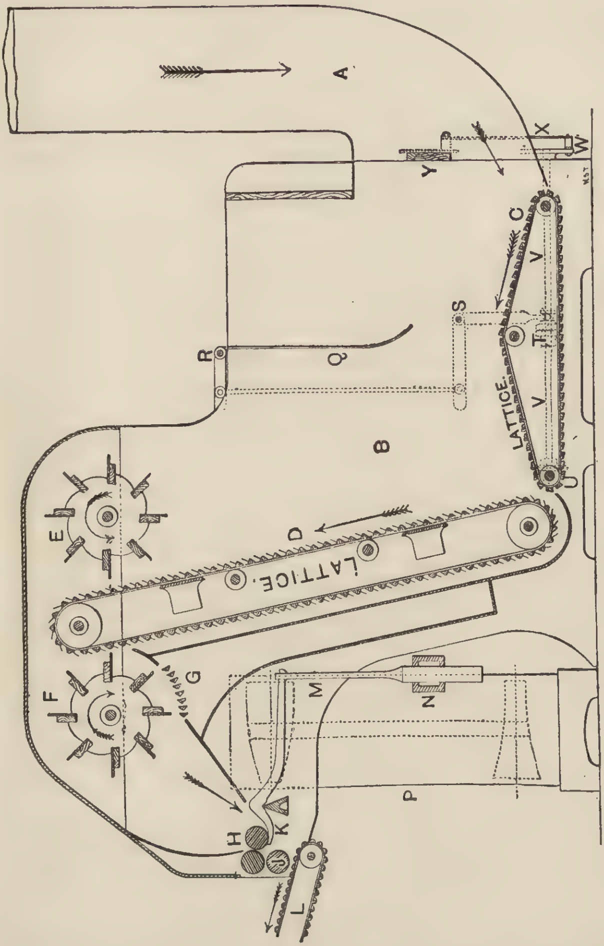


FIG. 16.

vantages the hopper feeder possesses, especially when we realise that the cotton as it is delivered by the rollers J

has been doubly regulated—first, through the spiked lattice being charged with cotton as it passes through the partially-filled chamber B, the surplus cotton being removed by the roller E; and, secondly, by the purely regulating arrangement at H and K.

So far as our description has gone we have presumed that the chamber B is kept from about half to three-quarters full of cotton. As this depends upon an attendant, who is liable to allow it to contain either too little or too much, a device has been arranged to keep the cotton in the chamber at a constant level (within narrow limits). To effect this, three or four feeler bars Q hang inside the chamber from a rod R. A lever on the rod is connected by other levers to a catch box T on the shaft V. As the chamber fills, the pressure of cotton forces the bars Q backwards, and these, acting through the levers, put the catch box T out of gear just at the moment when a crank W on the end of the shaft V has lowered a vibrating trunk door Y so as to stop the entrance for the cotton. This door Y remains closed until the bars Q are permitted to fall by gravity into their normal position. This, of course, puts the clutch box into gear again, and the door Y opens, thus allowing more cotton to enter.

A somewhat similar arrangement is made when the hopper is fed by a travelling lattice instead of a trunk, the lattice being automatically stopped or started according to the level of the cotton in the chamber B. Having described the particular hopper as illustrated, we may mention that other hoppers, though having the same general features, yet differ in details from this one. Some machines, for instance, have the evener and stripper rollers arranged with several rows of spikes, in such a manner that they protrude from the casing of the roller as they

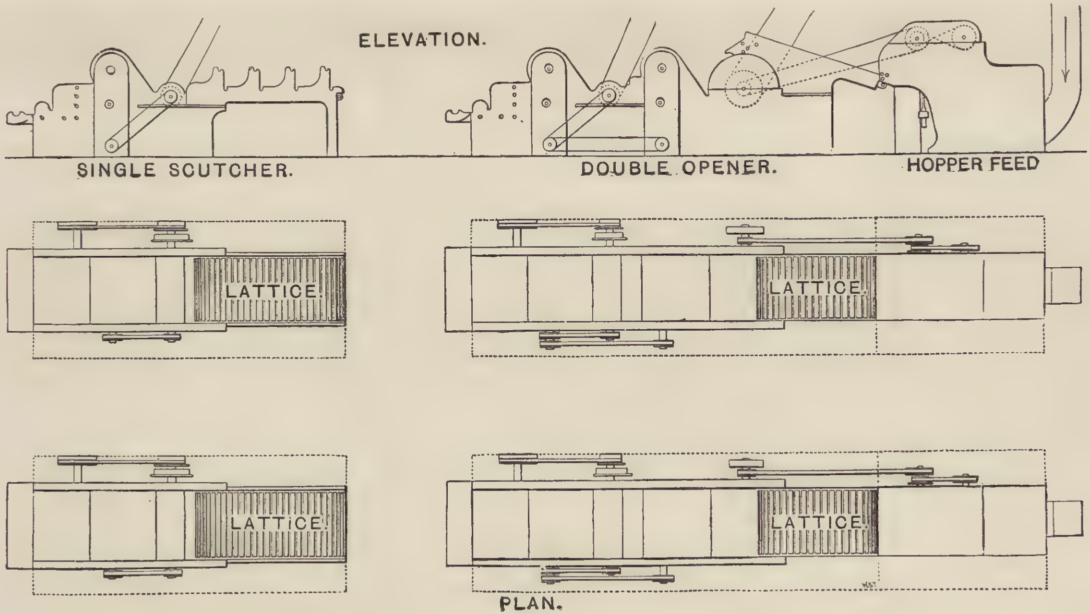

ELEVATION.
SINGLE SCUTCHER.
DOUBLE OPENER.
HOPPER FEED
LATTICE
LATTICE
LATTICE
LATTICE
PLAN.

Fig. 17.

strike the cotton from the lattice; but by means of eccentrics on the shaft they are gradually withdrawn inside the casing as the revolution continues. In this way any cotton that may have adhered to the spikes or pins will be cleared away. Another machine has applied to it a supplementary small lattice, moving very slowly, and in such a position that the cotton passing between it and the large one, which is moving much more quickly, is drawn out into a comparatively level condition.

A general view of how a hopper feeder is connected to an opener is given in Fig. 17, which also shows the general plan of these machines, and the relative positions of the scutchers in the same room.

CHAPTER V

OPENERS AND SCUTCHERS

We now come to a class of machines known under the general name of Openers. The machines previously described, although they open the cotton, do so in a preparatory sense only, and act chiefly as assistants to the machines about to be described.

Openers receive their name principally from the fact that they open the cotton sufficiently to extract from it the great bulk of the impurities it contains. The more delicate operation of continuing the opening process to an almost complete separation of the individual fibres is left to a future process, which will be noticed subsequently. It has already been mentioned that various mechanical methods have been adopted to attain this result; so, in order to

enable a thorough grasp of the subject to be obtained, several of the chief types of modern opening machines will be illustrated and described.

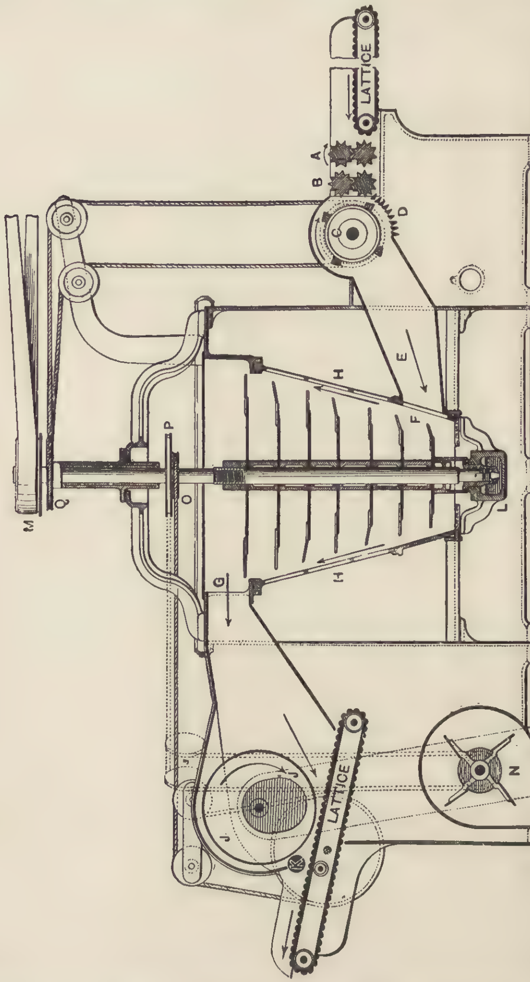
Commencing with a machine known as the "Crighton, or Vertical Beater Opener," which is extensively used in the opening of the short-stapled cottons (Indian and American), we will proceed at once to examine into its action.

The Vertical Beater Opener

The essential feature of this machine is a vertical conical beater (Fig. 18), consisting of seven sheet-steel discs, round the circumference of which are riveted a number of knife blades. The discs vary in diameter, and are threaded on to a vertical shaft, the smallest one (14 in. diameter) being at the bottom. From this they gradually increase in diameter to the top (28 in. diameter). The whole of the discs are firmly fastened in position by keys and by the nuts screwed on the shaft, and shown near the top disc on the drawing. It will be noticed that the knife blades do not all stand out from the disc in the same plane, they are bent out of the straight at different angles, the reason for which will be apparent as we trace the cotton in its passage through the machine.

There are several ways of feeding the cotton to the opener. For instance, it can be simply placed in a funnel-shaped entrance in any one of the three sides of the machine. A short trunk would then convey it to the lower part of the beater. Or a trunk from the room above can be connected with the funnel, and the cotton fed to the beater in this way. The best method, however, to feed, is to first pass the cotton through a small porcupine opener, which may be connected direct to the vertical opener, as shown in

Fig. 18, or the connection of the small machine may be by

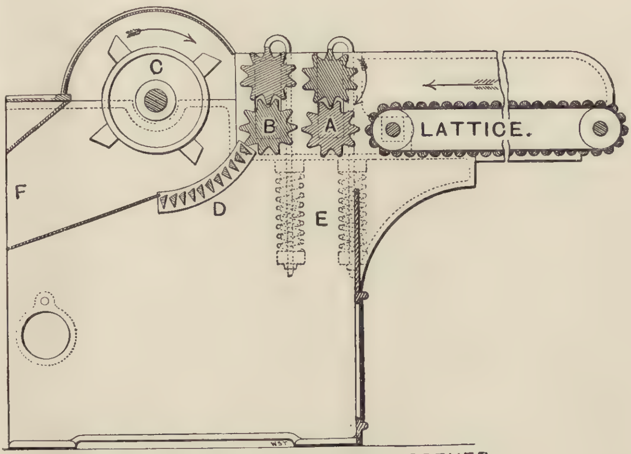


SECTION OF VERTICAL BEATER OPENER, COMBINED WITH SMALL PORCUPINE OPENER.

FIG. 18.

means of a trunk or lattice. An enlarged sectional view of

the small porcupine opener is given in Fig. 19. It differs in several details from a similar machine shown as a bale breaker in Fig. 14. The advantages resulting from the



SECTION OF SMALL PORCUPINE OPENER.

Fig. 19.

use of this machine are obvious. The cotton will be presented to the action of the beater in a fairly loose condition, and will therefore receive a less severe treatment and will be much better opened and cleaned.

The cotton is fed on to a lattice, and passing between the two pairs of rollers A and B (Fig. 19), where it is drawn, it is acted upon by a toothed beater C. The quickly revolving beater has the effect of breaking the cotton into small tufts, a certain amount of dirt being loosened and going through the bars D during the operation. Under the influence of a partial vacuum produced by the fan N (Fig. 18) in the passages and cage J, the cotton is drawn

down the tube E, and at its very entrance into the perforated casing which surrounds the beater it is brought in contact with the blades of the bottom disc. The high speed at which the disc is revolving (1000 revs. per min.) quickly loosens it sufficiently to allow it to rise and follow the current of air which is rushing through the machine. In doing so it comes naturally into contact with the blades of the next disc, when a further loosening is effected, after which the cotton again rises. This action is repeated by each disc until the top is reached, where the cotton escapes at G, in the direction of the arrows, to the revolving cage J. The perforations of this cage permit the fine dust and dirt to pass through, but it is impossible for the cotton to do so; it is consequently taken round until it is cleared from it by a delivery roller K and by the travelling lattice, the cotton being passed forward and allowed to fall over the end of the lattice on to the floor. Very often, however, machines are made so that the cotton goes through a beater to a lap end, where it is made into a lap. This effects a saving in labour and time, and also greater regularity is obtained in the finished lap for the card. It will be easily understood that while the cotton is under the action of the beater it will be continually thrown against the surrounding casing H. This casing is therefore made with a graduated series of holes, through which the heavy impurities are driven, the holes being largest at the bottom and gradually contracting in size to the top.

Having given a description of what happens to the cotton in passing through the machine, it will be of some advantage to inquire into the reason of the action that takes place. In this case we have a fan N, whose connection with the space within which the beater works is shown by the shaded portion at N, along upright passages on the outside of the

machine framing, called chimneys, to the shaded portion within the cage J; from here there is a direct passage to the top of the beater. Now, the sole object of the fan, which revolves at a very high speed (1000 to 1200 revs. per min.), is to exhaust the air from all the passages just mentioned, and by this means produce a vacuum. Knowing the fact that gravity is a force which prevents anything rising, we see the necessity of some power coming into action and forcing the cotton to the top of the beater. The pressure of the air supplies us with the requisite power, for outside the machine it will probably be almost at 15 lb. per square inch, while inside the machine it may be considerably less than this, according to the degree of the vacuum produced by the fan. If an opening is made, the air will be forced in by the outside pressure, and in rushing along the passages will force the cotton with it. This explains the reason of the cotton rising. From it we can also see that if the admission of air is not carefully regulated, or—what practically amounts to the same thing—if the speed of the fan is not regulated, it will be possible for the cotton to be rushed through the machine too quickly or too slowly, in one case resulting in insufficient opening, in the other case causing damage to the fibres and a considerable curliness in the appearance of the delivered cotton.

It ought to be noticed, in connection with this feature, that any current of air passing through the machine is well broken up by the disc blades of the beater, which are all running at different surface speeds, though having the same revolutions per minute. It is this fact which enables the vertical conical beater opener to exercise a discriminating action on the cotton. A direct current of air might carry along with it pieces of cotton, which vary in size, but the broken-up current cannot do this. It is almost impossible

for a piece of cotton to overcome gravity and to pass upwards until it is loosened sufficiently to come under the general influence of the upward current.

On account of the weight of the beater, and the high speed at which it is running, the machine must be strongly built to prevent vibration. The bottom of the shaft must also be well lubricated. In the sketch (Fig. 18) it is shown revolving on steel discs and pivots in a reservoir of oil, the friction being in this way reduced to a minimum. This machine is sometimes made in a double form. Where this is so, one end of a trunk would be attached to the opener at G, the other end leading the cotton to the bottom of the beater of the next machine. It is also made as a combined machine, *i.e.* a vertical opener with a horizontal beater and support attached. The following table gives a few particulars of the vertical opener :—

	Power.	Production.	Pulleys and Speeds.
Single opener	4 i. h. p.	30,000 to 40,000 lb. per week.	Beater pulley 14 in. dia., 1000 revs. per min.
Double opener	8 i. h. p.		

Horizontal Conical Beater Opener

In this machine (Fig. 20) we have the same essential feature for opening the cotton as in the vertical beater opener—namely, a conical beater. The similarity, however, is only to a certain extent apparent. Its action is modified in several important points, which will be noticed as the description proceeds.

The cotton is first passed through a small porcupine opener or bale breaker in the room above. It passes from this machine along the trunk A, in the direction of the arrows, to the entrance B of the beater casing. This passage of the cotton along a tube for some distance has

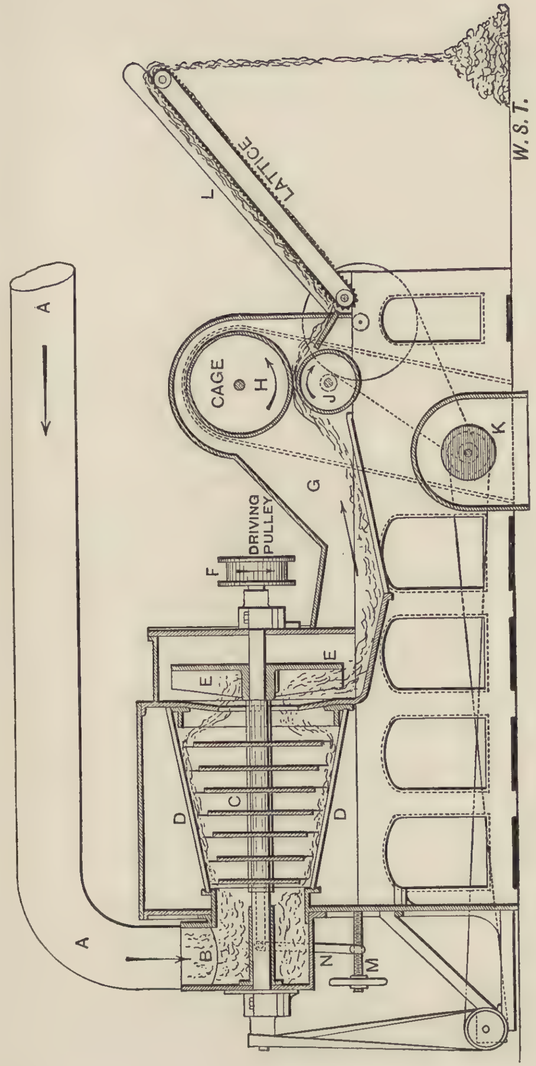
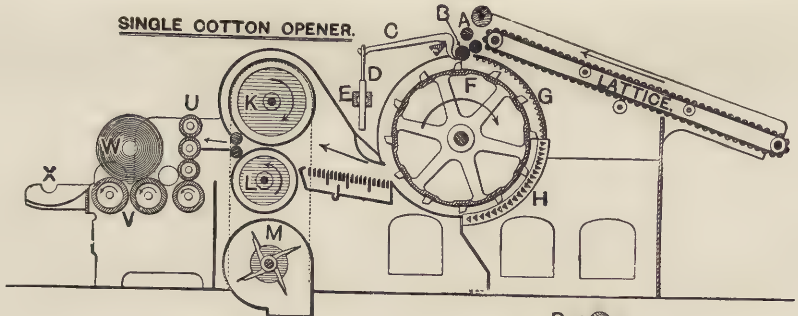


Fig. 20.

been performed under the influence of a powerful fan E on the beater shaft. This fan, by creating a partial vacuum of a sufficient degree of rarity, enables the current of air which rushes in to replace the air taken out to force loose cotton considerable distances along tubes, whether they be straight or curved. The machine, on this account, is often called an exhaust opener. The cotton, on entering the casing, is forced (not drawn) through the machine, and in its passage it naturally comes under the action of the blades of the beater. These open it out sufficiently to enable it to get rid of its larger impurities, which are driven through perforations in the casing D. When the cotton leaves the fan E, the current of air is maintained by a fan K acting through cages H and J. Consequently the loose material continues its journey, and, passing between the cages, which take from it its very light impurities, it is taken forward by a lattice L, over the end of which it falls to the floor; or it may be passed through a beater and made into a lap.

We will now point out a very noticeable difference between this form of beater and the vertical type. In the latter machine we saw that gravity played a very important part in enabling the machine to perform its work discriminately. In this machine, gravity, in the same sense, plays no part whatever; so, under the influence of the powerful fan E, the cotton goes through the machine quickly, and takes its chance of being opened out regularly. This may be a disadvantage for the strong, short-stapled, and hard, matted cottons, but it is a distinct advantage in the better classes. The fibres of these are more delicate and are consequently more easily damaged; and so, in passing through the beater quickly, they are opened sufficiently for their purpose, and yet are treated in a manner consistent with their structure.

Fig. 21.


SINGLE COTTON OPENER.
LATTICE.
A
B
C
D
E
F
G
H
J
K
L
M
U
V
W
X

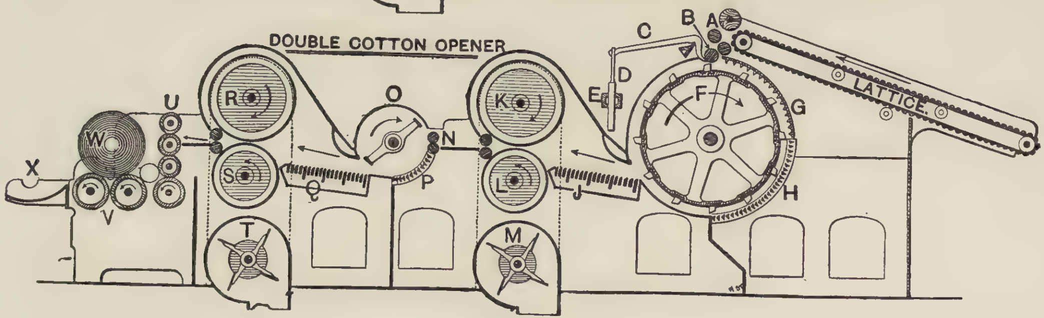

DOUBLE COTTON OPENER
LATTICE.
A
B
C
D
E
F
G
H
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X

Fig. 22.

In order to be able to alter the distance of the blades from the casing D, an arrangement is made so that, by turning the screw M, the lever N, which is connected to the casing D by links (one on each side), moves the casing in whichever direction it is necessary.

Suitable speeds for this opener are—

Beater and fan, 1100 to 1200 revolutions per minute for tubes 30 to 40 yds. long.

For shorter distances than these a slightly slower speed is preferable.

The fan is quite capable of causing the cotton to travel along the tube a distance of 100 to 200 yds.

The blade beater pulley is 10 in. diameter, and the speed should be about 1400 revolutions per minute.

The production varies according to the kind of cotton being worked, but with beater and lap part applied its average will be about 25,000 lb. per week of $56\frac{1}{2}$ hours.

Large Porcupine Cylinder Opener

Another form of opener, which is extensively used for American and Egyptian cotton, is shown in Fig. 21. The cotton is fed upon the lattice either by hand or by the hopper feeder, as already explained. It travels forward until it comes directly over the centre of a large revolving cylinder (see also Fig. 23). The feed arrangement of the machine is placed here because this position enables a large cleaning and opening surface to be obtained. The cotton passes between two fluted feed rollers A (3 in. diam.), and also between a pedal roller B (3 in. diam.) and a series of pedals C. This pedal arrangement actuates a regulating motion, the cone drums of which control the amount of cotton going through to the cylinder. (A full detailed description of the regulating motion will be given when

dealing with the scutcher. A more detailed account of the action of beater and lap end will also be given under the same head.)

Directly the cotton emerges from between the roller and pedals, it is struck by the teeth of a large revolving cylinder (37 in. diam.). The teeth of this cylinder carry the cotton round in the direction shown, the tendency of the cotton to fly off from the teeth during the revolution causing it to be thrown with some force against conical teeth on the under side of the cover-plate G. This action loosens it considerably, so that when it arrives at the dust bars H its contact with them loosens it still further, and at the same time the heavier dirt is driven through the spaces between them. A strong current of air, induced by the fan M acting through the revolving cages K and L, diverts the cotton from the cylinder (from which it is stripped by a stripping rail) and causes it to traverse a passage over the dust bars J and on to the cages. Its condition in going from the cylinder to the cages is sufficiently loose to allow a certain proportion of dirt to fall out and pass between the bars, a box under the grid being specially made to receive it. The cages take the light dust out of the cotton, and their revolution also conducts it forward between the cage rollers to the lap end, where the sheet as it comes from the calender rollers U is formed into a lap W. Instead of the cotton being made into a lap after passing the cages K and L in the single opener, it is more often passed through the beater feed rollers N and acted upon by a beater O, as seen in the double opener, Fig. 22. This continues the opening, and drives a further proportion of impurities through the bars P. The cotton then passes over the bars Q to the cages R and S, and from there to the lap end, where a lap is formed. The addition of this extra beater and lap end

also dispenses with the breaker scutcher, thus saving its cost and the wages of the minder.

It is quite apparent that this machine is bound to extract from the cotton a very large proportion of the heavier dirt, the whole arrangement of working parts combining in the best way to produce this result. An enlarged view

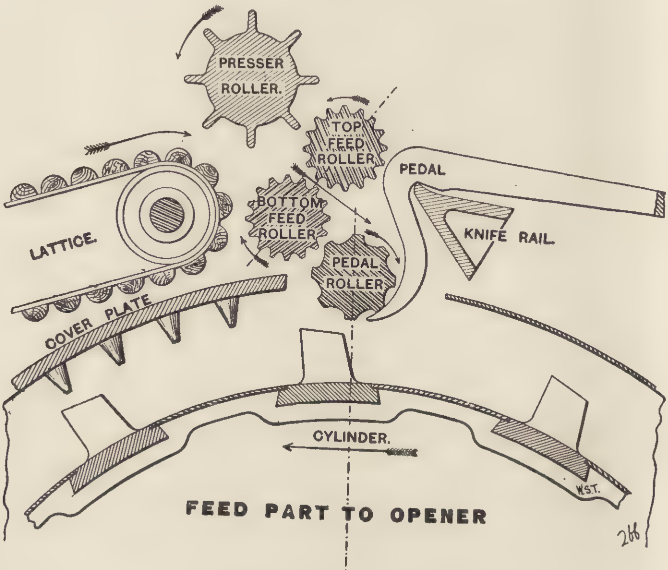


FIG. 23.

of the feed part is given in Fig. 23. From it we notice several features that are of importance. In the first place the teeth of the cylinder are of such a shape that they carry the cotton from the pedal nose without in the slightest degree damaging it, and it is practically impossible for them to get clogged with cotton. They are placed around the cylinder in rows, but in such a manner that no two rows of

teeth act on the cotton at the same spot. This gives, when the speed of the cylinder is taken into consideration, a rough kind of combing action to the mass of fibres presented to them. It will also be seen that the dashing of this loosened material against the conical projections on the under-side of the cover-plate has such an effect that a quantity of the broken seeds and leaves are freed, to such an extent that directly the grids are reached they are immediately thrown out.

Another important feature to notice is that the cotton is delivered in the same direction as the revolution of the cylinder. The cotton in this way is withdrawn from between the pedals and roller in a perfectly natural manner. This would not be the case if the revolution of the cylinder was in the opposite direction, for the fibres would be struck round the sharp nose of the pedal, with probably a damaging effect. A point of minor importance is the arrangement of the fulcrum of the pedals. As seen on the sketch, it consists of a knife-edged rail which goes across the machine, the pedals having a V-shaped recess cut in them to rest upon it. This method ensures a far more delicate adjustment of the regulating mechanism than that of centering the pedals upon a stationary shaft.

	Power.	Production.	Speeds.
Single opener . . .	5 i. h. p.	25,000 lb. per week	Cylinder, 450 revs.
Double opener . . .	10 i. h. p.		Beater, 1,000 ,,

A section of a well-known type of opener is given in our next illustration, Fig. 24. The cotton is delivered to the machine by means of a lattice and a pair of feed rollers A. It is received from these by a large spiked cylinder B, which carries it upwards. In its motion it is thrown against nugs or teeth on the under side of the cover-plates C. This has a very beneficial effect in loosening the fibres

and liberating the heavy impurities, these impurities being

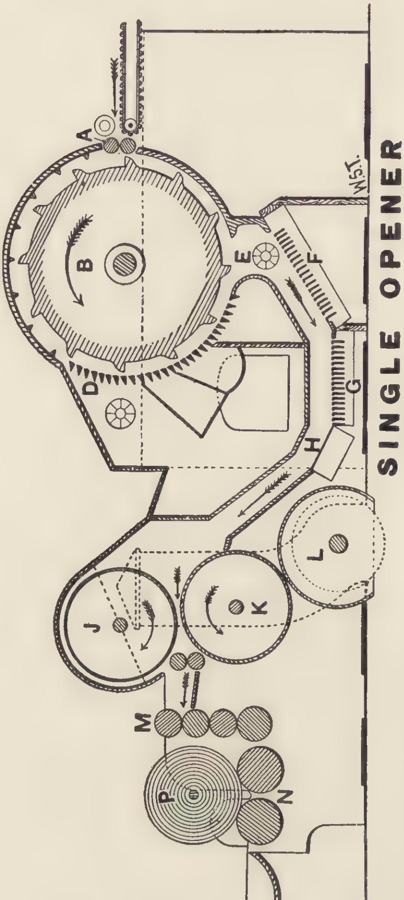


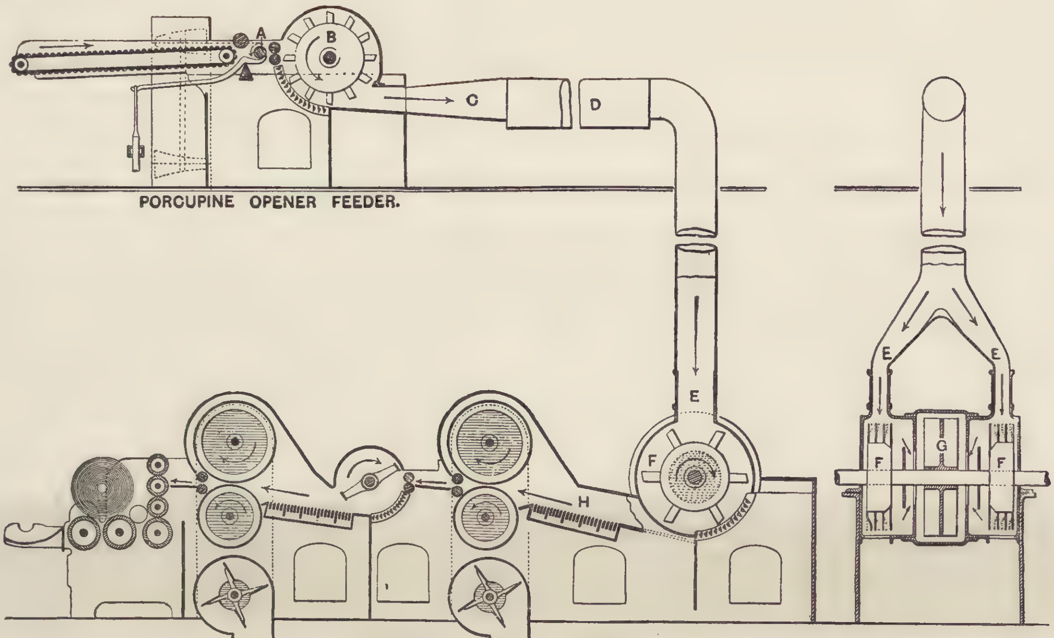
FIG. 24.

discharged through a series of grate bars D. After going

through about three-quarters of a revolution of the cylinder B, the cotton is stripped from it, and travels along the passage H under the influence of a current of air produced by the fan L. Almost a perfect control over the current is obtained by the introduction of draught regulators at E. A very even distribution of the cotton is by this means obtained in the passage to the cages, and results in a lap, the sheet of which is very compact and regular. The cotton passes from the cages to the lap end in the usual manner. A double form of this opener has a beater and another set of cages attached, similar to the double machine represented in Fig. 19. A pedal feed arrangement is also very often applied instead of the feed rollers shown in the sketch.

Exhaust Opener

In Fig. 20 a drawing was given of an opener, the fan of which is capable of producing a current of air sufficiently strong to cause cotton to travel some distance along a tube to the beater. It will be seen that this is one of several methods of taking the cotton direct from the mixing-room to the opening machine, in this way dispensing with carrying, and the accompanying expense of employing hands for that operation. We now give an illustration of another machine which serves a similar purpose, an examination of which in Fig. 25 will show very clearly its action. The cotton is fed to a small porcupine opener in the mixing room above, a very important feature of this small machine being a regulating pedal motion, which ensures a regular supply of cotton to the machine in the room below. After passing through the machine, a current of air generated by a fan G on the cylinder shaft in the exhaust opener causes



HORIZONTAL EXHAUST OPENER.

FIG. 25.

the cotton to travel along the tube C. In doing so it is made to pass through dust trunks D, containing vertical bars over which the cotton moves, and naturally its impeded motion through them causes a certain proportion of dirt to fall down between the bars into boxes below. Continuing its course along the tube, it enters the opener by means of a divided trunk E, E, and these conduct it into contact with the revolving cylinder beaters F, F. The cotton is well opened at this point, the loosened dirt escaping through the grids under the cylinder. The fan G frees the opened fibres from the cylinder, and vanes of special form send it forward along the passage H. In this passage it comes under the influence of the fan acting through the cages, from whence the material goes through the remainder of the machine, which is the same as the corresponding part of the double opener shown in Fig. 19, so that it is unnecessary to repeat what was there said when describing that portion of the machine.

An advantage resulting from the division of the trunk at E, E, and the use of two beaters with the fan between, is that the cotton gets well distributed in the passage to the cages, a very equal lap with good selvedges being by this means obtained.

In machines of the description just given, it is quite obvious that there must be some positive connection between the small porcupine machine and the exhaust opener, in order that they may both act mutually towards each other. Whatever method is adopted it must fulfil the condition of automatically stopping either machine whenever the other ceases to work. For example, laps are continually being made, and at the completion of each lap the exhaust opener automatically stops; this stoppage is communicated to the small porcupine opener, which also stops at once—other-

wise the tubes would be blocked with cotton, resulting in considerable waste of time and material.

It is sometimes used as a complaint against an exhaust opener that the carrying of the cotton along tubes and dust trunks causes it to form into roller and ball-shaped masses. While this is so it is also true that this peculiarity is the cause of little if any effect of an injurious character upon the fibres in passing through the opener.

	Power.	Production.	Speeds.
Porcupine opener feeder . . .	2 i.h.p.	20,000 to 25,000 lbs. per week, 56½ hrs.	Cyl., 900 revs. per min.
Exhaust opener .	12 i.h.p.	. . .	Cyl., 900 revs. per min. Beater, 1200 revs. per min.

Scutchers

Although the cotton has now passed through the opener, and has had extracted from it probably about 4 per cent of impurities, it is not in any sense of the term what would be called clean. The opening process is therefore continued under the name of scutching, which literally means beating or whipping. It is, as a matter of fact, a repetition of the action of the beater in the double form of opener, the object, of course, being to drive out as much as possible of the impurities the opener has failed to expel. We will first give a general description of the action of the machine, after which we will proceed to examine very closely its various features. A longitudinal section through a single scutcher is shown in Fig. 26. Three or four laps are taken from the opener and placed upon the travelling lattice. The friction produced by their weight on this moving lattice causes them to unroll and go forward in the direction

of the arrows. By this means we got the four layers of cotton combined into one as it emerges from beneath the lap nearest to the beater. In continuing its passage it leaves the lattice and passes between a roller A and a series of pedals C, centred on the knife rail D, the regulating mechanism being operated through this pedal arrangement. From the pedals it is taken by a pair of fluted rollers and brought within range of the quickly-revolving beater H. The beater accomplishes a very effective opening and cleaning operation, the bars I helping considerably to render this performance satisfactory. From here the cotton is taken by a current of air over the bars J, where dirt is deposited, to the cages, which by their revolution conduct it forward to the lap end, where the finished lap is made.

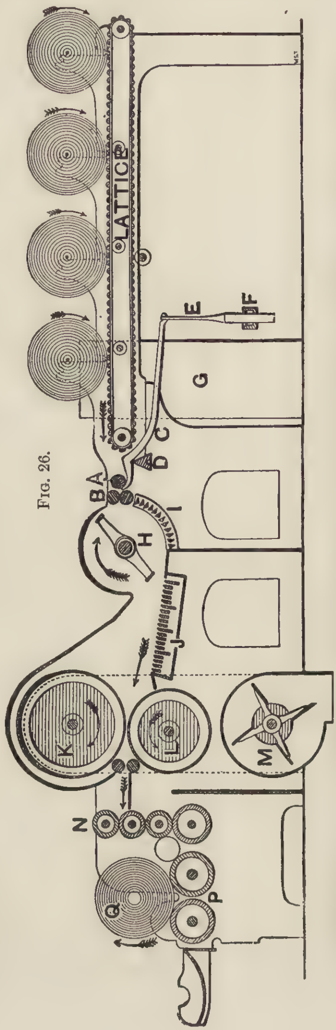


Fig. 26.

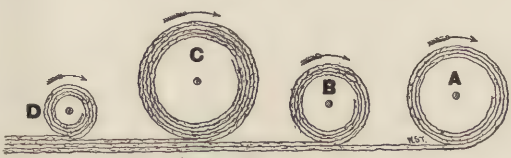
SECTION OF SINGLE SCUTCHER DOUBLING FROM FOUR LAPS.

Having given this general sketch of the scutcher, we will now enter upon a detailed account of its important actions, and at the same time investigate the reason for the mechanical means employed to carry them out successfully. It must be borne in mind that the object to be attained in spinning is to obtain a perfectly regular length of yarn exhibiting no variation either in diameter or weight for any given length. We may say at the outset that this standard of perfection is never reached, but at the same time the whole tendency of the processes we employ is to approach as near to it as the conditions under which the work is performed will permit.

The sooner we commence to bring the cotton into the regular condition mentioned above, the better will it be for its further treatment. In the opening process it is sufficient if the laps from the same machine can be made all to weigh the same within the narrow limit of, say, $\frac{1}{4}$ lb. more or less in a 33 lb. lap. This would be considered good regulating. But if we take a small quantity—for instance, a square yard of the lap instead of a full lap—we should find a greater difference when compared with other square yards from the same lap; and by taking smaller portions still, the percentage of difference would increase greatly. Every effort is therefore made to get this irregularity eliminated, and for this purpose two methods are generally adopted. One has already been mentioned—namely, that by means of the cone drums. The other is known under the name of doubling. Both systems are employed in the scutcher.

We will deal with the doubling of the laps first. If a portion of the sheet of a lap from the opener is held up to the light it is seen to consist of thick and thin places, irregularly distributed over its surface. If the lap were allowed to go through the machine in this state the thick

and thin places would probably remain so. To prevent this happening another lap with similar thick and thin places is placed on the top of the first one. By adopting this course it is highly probable that a number of the thick places in one lap will come over a number of thin places in the lap below, and *vice versâ.* In this way we get a more uniform lap, but of double the thickness. If another lap is placed upon these two, the probability of the inequalities neutralising each other is increased, and by going a step further still, and making four laps into one, we advance still nearer towards uniformity in the combined lap. We already know that there is comparative regularity



DOUBLING FROM FOUR LAPS

FIG. 27.

in each full lap, but the uniformity this doubling of laps has produced is seen when small quantities of the lap are compared with each other, and this is the very object for which we are working. As we get deeper into the subject we shall perceive that it is around this principle of obtaining equal weights of equal small portions of silver or yarn that the success or failure of the future operations turns.

A sketch is given in Fig. 27 showing how the laps unroll and pass under each other upon the lattice which conducts them to the feed rollers. This same sketch will also serve to illustrate another point of importance, although it is of an elementary character. On reference to it, the laps A, B, C, D, all vary in diameter. This is done designedly, the

object in view being to keep up the continuity of the fourfold thickness of lap in passing through the feed rollers. As arranged, this is an easy matter, for directly a lap is finished it can be replaced immediately. But if three or four were unrolled at once, their replacement would take much longer, and the risk would be run of a thin place occurring in the combined lap through the piecing not being performed quickly.

We now arrive at the point in the treatment of the subject when it will be of advantage to deal a little more fully with the other method of obtaining equalisation of the lap. It has already been mentioned and illustrated when describing the opener, so that what is now said in explanation of its action will apply with equal force to its application in that machine. We have observed how the doubling of the laps has a disposition to reduce irregularities in thickness, but it is only a commencement towards the attainment of the object in view. So we go a step further in the right direction by passing the cotton between a fixed revolving roller and a series of pedal levers, the arrangement being known as the piano feed or pedal-regulating motion. The pedals, to the number of about sixteen, are disposed side by side across the width of the machine. If the sheet of cotton were perfectly regular, all the pedals would occupy the same position as it passed forward, but if a thick part went through, the particular pedal or pedals over which it traversed would be depressed. A thin portion would have the opposite effect to this, and cause the pedal to rise above its correct position. Now, knowing that our aim is to deliver to the beater equal quantities of cotton in equal times, we can see that this would be the case so long as the thick and thin places were equally distributed throughout the sheet. The action of this state of things

on the pedals would be to depress one half of them, and cause the other half to rise, thus neutralising each other. In the lap, however, it is only momentarily that a condition like this occurs; either thick or thin places predominate continually, the variation sometimes being very slight, at other times excessive. A small sketch (Fig. 28) is given explanatory of this point. A transverse section is supposed to be made through the centre of the pedal roller and pedals while the cotton is going through. The varying conditions both in the thickness of cotton and the position of the pedals is clearly shown, and may be taken as the general action of the motion. It must, however, be remembered that, no matter how the individual pedal may

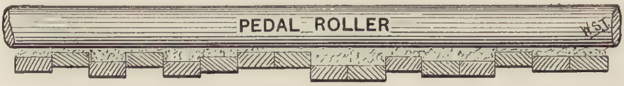


FIG. 28.

be disturbed by thick or thin pieces of cotton, so long as the average thickness keeps the same the speed of the pedal roller will not vary.

If the thick places exceed the thin ones, we can clearly see that too much cotton is being fed, while a reverse state of things, in which the thin overbalance the thick places, shows that the cotton is being fed insufficiently. We can also understand that if the supply is too thick, a less quantity of it must be sent through. This means that the speed of the roller must be reduced: and correspondingly increased to deliver the same quantity of a thinner feed. It will now be obvious that the correct variation in the speed of the feed rollers, according to the thickness or amount of cotton fed, is a very important factor, so we will

proceed to investigate the system of driving generally employed to obtain this variation.

For our purpose, reference will be made to the diagram Fig. 29, and for the sake of simplicity, it may be assumed that the pedal is a straight yielding surface instead of being, as is generally the case, slightly curved at the nose. Suppose the pedal roller takes $\frac{1}{8}$ in. thickness of lap A 1 through, and 6 in. of its length, A, B, is delivered to the beater in one second. Remembering the condition of

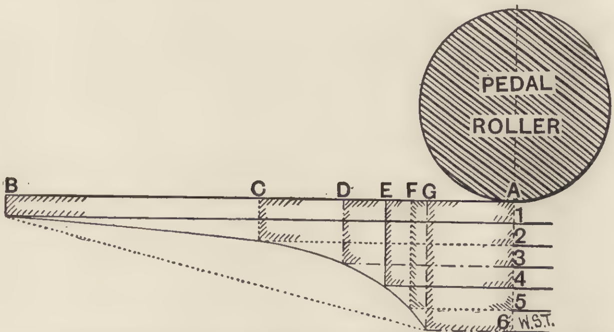


DIAGRAM OF REGULATOR CONE DRUMS

Fig. 29.

equality—namely, that an equal quantity must go through every second—we can easily see that if the thickness of the lap is increased to $\frac{1}{4}$ in., as at A 2, or is otherwise doubled, the length to be delivered in order to equal the first quantity must be 3 in., A, C, or one-half. The speed of the roller must therefore be reduced to turn only this amount through —in other words, its speed must be reduced to one-half. Let another $\frac{1}{8}$ in. be added to the thickness, making the total $\frac{3}{8}$ in. A 3, the length of a $\frac{3}{8}$ in. lap in order to contain the same amount as is contained by $\frac{1}{8}$ in. lap 6 in. long

must be 2 in. long, A, D. This is equal to saying that since the thickness is now three times what it was originally, the length delivered is reduced to one-third the first length, and the speed is reduced to the same extent. By continuing the process of adding to the thickness we reduce the speed, as is shown above, in what is termed inverse ratio. The following table shows at a glance the result of this reasoning, calling the commencing thickness 1, which may be $\frac{1}{8}$ in. or any other dimension, and whatever the speed of roller may be we will call that also 1 :—

If a thickness of	1	is fed, the speed	of roller will be	1
"	2	"	"	$\frac{1}{2}$
"	3	"	"	$\frac{1}{3}$
"	4	"	"	$\frac{1}{4}$
"	5	"	"	$\frac{1}{5}$
"	6	"	"	$\frac{1}{6}$

On referring to the diagram, Fig. 29, we shall see that by joining all the thicknesses together, according to the table, a curve is produced. This, as well as the table, proves to us that the variation in speed is not in direct proportion to the length delivered, but varies in the proportion denoted by the curve. Those readers who have the necessary knowledge will readily see that this curve is the Hyperbola; others will recognise it as the curve which represents Boyle's Law of Pressure and Volume, equalling a constant—it is, in fact, the same principle; for in the table, if we multiply any thickness by its corresponding length, we get the same product in every line. If the fact is thoroughly grasped that the length delivered from the pedal roller per unit of time (say per second or per minute) multiplied by the thickness at that time must always have the same product, there will be no difficulty

in accounting for the curved form of the drums which are used to drive the roller.

It now remains to put into a practical form the reasoning we have employed. In the first place we must work within defined limits; a quarter of an inch will therefore be taken as the minimum thickness, and 1 inch as the extreme thickness. With these numbers given to us, and also the speed of the bottom cone drum, which for convenience may be 100 revs., we will design a pair of cone drums to vary the speed of the pedal to work within the limits given. The bottom cone drum runs at a constant speed; the top cone drum varies, since it drives the pedal roller, the variation depending upon the average thickness of cotton going forward. Now construct a table as follows, leaving the last column out:—

Thickness.	The Speed of Top Cone Drum will be
When $\frac{1}{4}$ in. is going through	$x = 220$ revs.
When $\frac{1}{2}$ in. is going through (which is twice the first)	$\frac{x}{2} = 100$ „
When $\frac{3}{4}$ in. is going through (which is three times the first)	$\frac{x}{3} = 66\frac{2}{3}$ „
When 1 in. is going through (which is four times the first)	$\frac{x}{4} = 50$ „

This table tells at a glance that the variation in speed of the top drum is as one to four. We are now enabled to fix the extreme diameter of the two drums. With this in view they may each be made 8 in. and 4 in. in diameter, as shown in Fig. 30; and at the same time the speeds resulting from these diameters are easily found—

$$\frac{8 \times 100}{4} = 200 \text{ revs.}, \frac{4 \times 100}{8} = 50 \text{ revs.}$$

By filling in these speeds in the table it is a simple matter

to find the intermediate speeds at equal intervals along the cone drums as the strap moves from one end to the other.

Since $x = 200$ revs., $\frac{x}{2}$ will equal 100 revs., and $\frac{x}{3} = \frac{200}{3} =$ $66\frac{2}{3}$ revs.

From these speeds the diameters requisite for obtaining

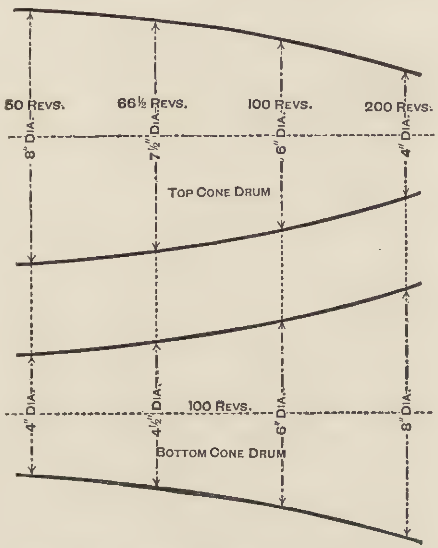


DIAGRAM OF REGULATOR CONE DRUMS.

FIG. 30.

them are readily found, remembering, of course, that the same strap has to fit all the way along the drums, and that the sum of the diameters opposite each other on the top and bottom cone drums should $= 8 + 4 = 12$. On reference to our sketch, Fig. 26, we observe that the 4 in. diam. has 200 revs., and the 8 in. diam. has 50 revs. In the same

descending proportion we shall get the diameter for the $66\frac{2}{3}$ revs. equal to

$$\frac{8 + 4 \times 66\frac{2}{3}}{100 + 66\frac{2}{3}} = 4\tfrac{4}{5} \text{ in.}; \ 12 - 4\tfrac{4}{5} = 7\tfrac{1}{5} \text{ in.}$$

In a similar manner the bottom drum, revolving at 100 revs., will, when driving the top drum at the same speed, require an equal diameter; so that when the strap is on this point the diameters will be equal to each other—viz. 6 in.

Four diameters have now been obtained in each drum. By joining their extremities we get the curved outline which is characteristic of this motion. It must be understood that the calculations made are for the centre of the strap, both in width and thickness, the actual diameters of the cone drums will in consequence be the thickness of the strap less than those given. It need scarcely be added that a similar method of working applies equally as well to the cone drums of the fly frame. When we come to deal with that machine, however, a further consideration of the matter will then be given, and the problem viewed from a different standpoint, with a more extended application of the principle involved. Sufficient has been said to make it clear that for perfect regulating the hyperbolic curvature of the cone drums is absolutely necessary.

The next step in our explanation will be to show how the cone drums are applied in order to fulfil their special function. For this purpose drawings are given in Figs. 31, 32, and 33. During the passage of the cotton under the pedal roller the pedals will be depressed, the amount of depression varying according to the thickness of material going through. Hanging from the other end of each pedal is a pendant, or, as it is sometimes called, a fishtail, the

latter name being given to them on account of the fan-shaped portion at the bottom of each one. These pendants pass through and are guided in their movements by a rail. Between each pendant in the rail is placed some form of friction bowls, arranged so that a change of position of

FIG. 31.

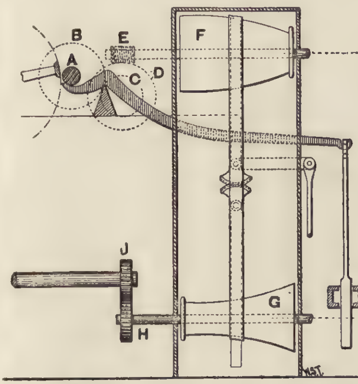
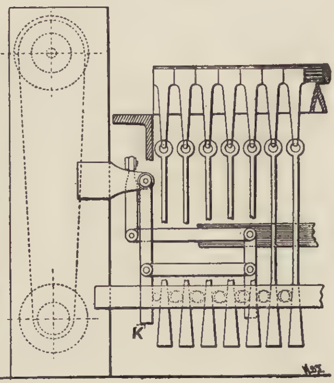


FIG. 32.



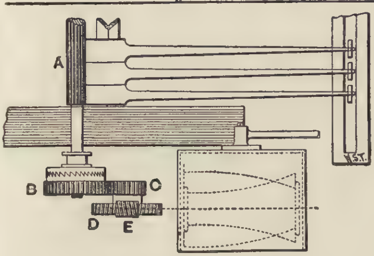


FIG. 33.

any pendant up or down will affect the position of all of them that are between itself and the cone drums. This will be made clear by referring to Fig. 32.

It will be seen that if a pendant is lifted up, which happens when a thick piece is passing under the roller, the tapered portion must displace the bowls in doing so, and

through them the other pendants will be moved on one side. This displacement is naturally transferred to the end of the rail, where it affects a series of levers through which the strap of the cone drum is moved. The remarks previously made in regard to the average thickness not affecting the speed will perhaps now be better understood. We can clearly see that if an excessively thick piece lifted a pendant, the bowls would move outwards and would quickly move the strap of the drums towards the smaller diameter of the bottom cone drum; but if at the same time a thin piece went through, the pendant would drop and the bowls come inwards, thus neutralising the previous action. It is only when the average action of the whole of the pedals is disturbed that the end lever K is moved either in or out.

The bottom cone drum, as we have seen, is driven at a constant speed from the lap end through the wheels J and H. The strap for an average thickness works in the middle of the two drums. If the strap is moved to the large end of the driving cone it will drive the top cone quickly, while if moved to the small end the top cone drum will revolve slowly. The driving from the cones is distinctly shown, and consists of a worm on the cone-drum shaft, gearing into a worm wheel, on the boss of which is a pinion working into a spur wheel on the pedal roller. This wheel is loose on the end of the roller, and can only drive when put into gear with a catch box on the same shaft, the object of this arrangement being that the feed can be stopped on the completion of a lap.

Readers will fully recognise that the efficiency of this regulating motion depends upon the exact arrangement of the levers and the elimination of friction. The first condition of accuracy cannot be attained with levers to the degree sometimes considered necessary, on account of

each lever moving through a portion of a circle, and resulting in what is termed harmonic motion. This defect is overcome when, instead of levers, the connection with the cone-drum strap fork is made by means of a thin, flexible wire rope. An arrangement of this kind has

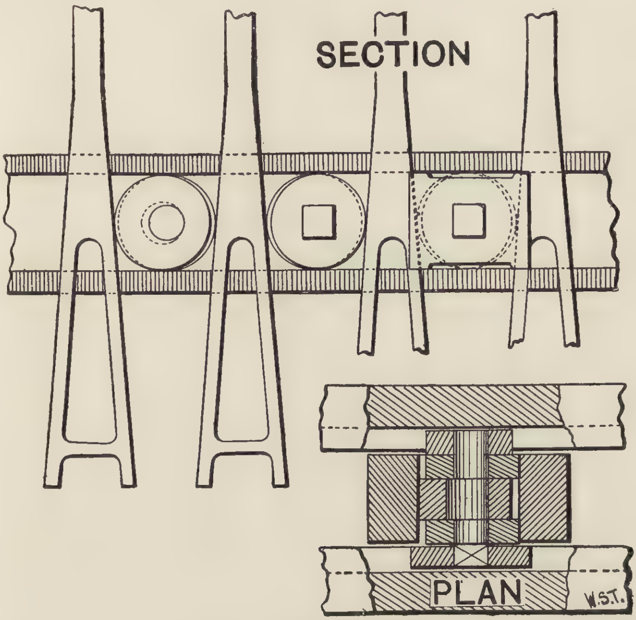


FIG. 34.

been applied to many machines with very successful results, any slight tendency of the wire to stretch being compensated for in a suitable manner.

The other condition of friction is also very important, for unless the pedal acts instantaneously on the drums we reduce the chance of perfect regulation. Two enlarged views are therefore given in Figs. 34 and 35, which show

the methods generally adopted to reduce the friction in the bowl rail. One or more bowls were formerly placed between each pendant; but it will readily be seen that if two adjacent pendants were lifted at the same time,

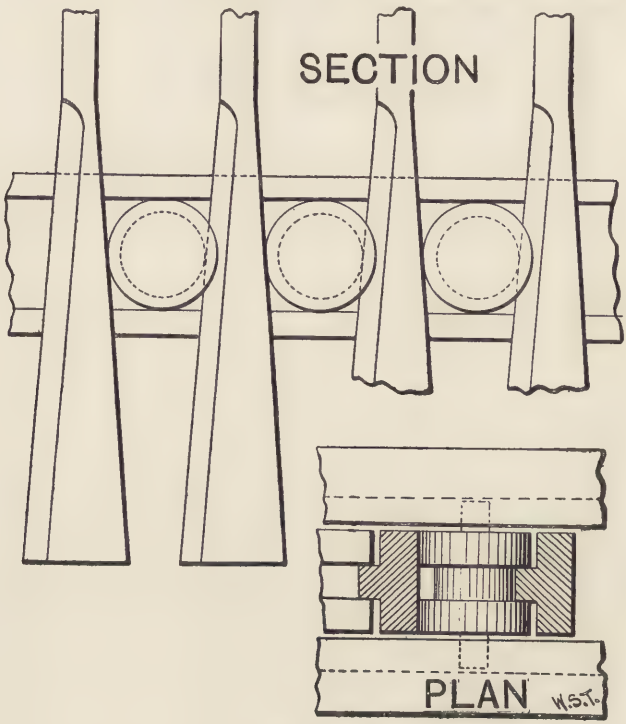


FIG. 35.

considerable friction would be developed, through the bowls turning against each other or rubbing against the sides of the pendant. This fault has been remedied in the two ways shown.

Fig. 34 gives a section and plan, and from it we see that

each pendant bears against its own bowl. These bowls are, however, threaded upon the same shaft, but in such a way that the middle one is on an eccentric portion of the shaft, and so can revolve independently of the two side ones. By this means no interference with the pendants can take place, each working up or down without affecting the adjacent one. To keep the eccentric portion in position, one end of the shaft is made square. On this is threaded a square slide, which runs along a smooth recess cut in the inside of the rail. The other end of the shaft also carries a loose bowl, which helps considerably to reduce the friction as the bowls move backwards and forwards along the rail.

Another method, given in Fig. 35, is very effective for the same purpose. Here we have a small shaft carrying three bowls, the middle one being smaller than the two side ones. The section of the pendants bearing against the bowls is T-shaped, so that the flat portion is against two side ones, while the narrow part bears against the smaller bowl. Each bowl can turn independently of the other, so that very little friction can possibly be developed.

The next feature to notice is the feed arrangement, and its importance demands some little consideration. It has already been touched upon, but we will now enter more into detail respecting it. In the first place the disposition of the rollers and pedals will be examined. For this purpose Figs. 36 and 37 are given. Fig. 36 represents the usual method of delivering low-class cottons to the beater. There are several reasons for this procedure. The cotton, having a short-stapled fibre, is by this means brought closer to the beater blade, with the result that it is not knocked away in lumps, which would otherwise happen, but in small detached portions.

Low-class cottons are generally fed more thickly and irregularly than better kinds; consequently, in passing under the action of the beater it is the more easily cleared from the comparatively sharp edge of the pedal nose, and its short length of fibre stands less chance of being damaged in doing this. It is almost impossible for the fibres to get crushed between the beater blade and the pedal nose, unless through carelessness in setting. The fulcrum of the pedal is also set so as to allow the pedal, when depressed, to move

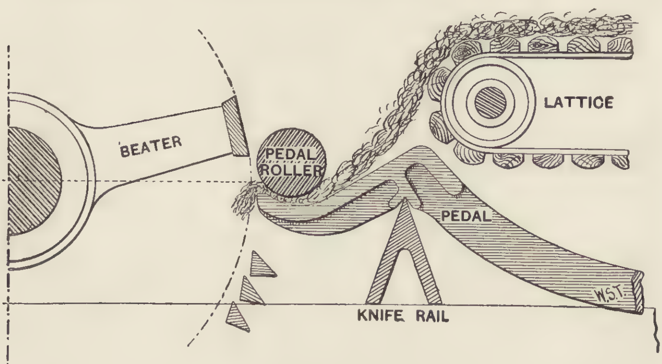


Fig. 36.

away from the beater, and thus prevent a possible source of mischief.

In dealing with the better kinds of cotton another set of conditions comes into play. More regular results are required; the fibres are longer and more delicate, so the cotton is passed through the pedal motion, and from there it passes between a pair of feed rollers (Fig. 37), the speed of which in relation to the pedal roller is arranged to produce a slight draft, and is brought into contact with the beater. Instead of being struck over a pedal nose, as in the first case, it is struck round the bottom roller, in

this way minimising the possible damage to the fibres, and at the same time allowing the blow to draw out the cotton instead of breaking it from the grip of the rollers. Carelessness in respect to accurate setting of the pedal in Fig. 36 or the feed rollers in Fig. 37 leads to enormous damage to the material. This will be very obvious when it is understood that every inch of cotton receives a very large number of blows of a very severe character, so it will be apparent that every effort must be made to confine this extreme action to the special work it has to perform

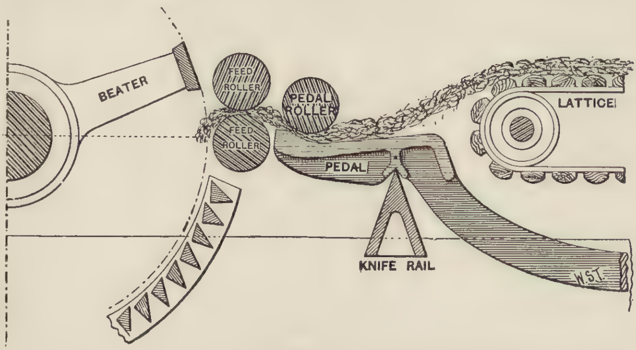


Fig. 37.

—viz. opening and cleaning. Many evils result also through faulty setting. Cat-tails are formed, which are corded portions of cotton, made so by an unusual length of cotton hanging from the rollers, and the high speed of the beater in striking it as it passes causing it to instantly curl itself into a stringy condition. The cotton, again, is crushed if the rollers are set too closely, and their strength very materially lessened. A delicate adjustment of the pedals is essential, the whole series being arranged on a knife edge, so that any irregularity is compensated for immediately.

In considering the question of the beater used in the

opener and scutcher, it is usual to leave the matter in the hands of the owner of the machine, on account of the great divergence of opinion prevailing as to the advantages or otherwise resulting in the use of a two- or three-bladed beater. A general idea of the question will therefore be given, and a sketch of the two kinds is shown in Figs. 38 and 39. It will be observed that each beater is the same diameter (16 in.), and also that they are strongly made. The blades running across the width of the machine are made of steel, and are firmly riveted to three or four sets of arms keyed

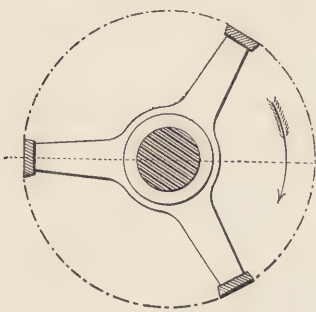


FIG. 38.

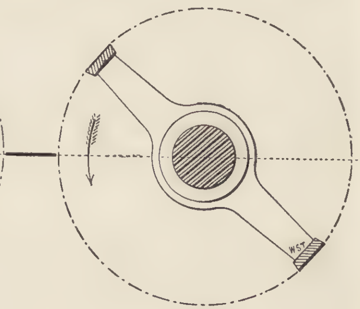


FIG. 39.

on the shaft. Each edge of the blade is bevelled, in order to strike the cotton clearly. The amount of the bevel is not, however, sufficient to have a cutting action on the emerging cotton. As the edge is dulled through continual usage, it is now usual to reverse the beater when this happens, both ends of the shaft being made alike for this purpose; this brings the other bevelled edge of the blade into use.

The specification of the beater has already been remarked, and from what was said the idea would be conveyed that the force of the blow given to the cotton

was a very important factor. Now, we must recognise that the force of a blow depends upon two things—the weight of the object dealing the blow, and also its velocity; and, in respect to this, the dependence is not on the velocity in a proportionate sense, but upon its square. To give an illustration, this means that a blow struck by something moving at two feet per second would be four times more forcible than if the velocity was one foot per second.

In comparing the illustrations we see clearly that the three-bladed beater is the heavier one; so that if both are running at the same number of revolutions it will not only give 50 per cent, or $1\frac{1}{2}$ times, more blows, but each blow will be more forcible than the blow given by the two-bladed beater, and this for two reasons. One is, the increased total weight just mentioned; the other demands a little more advanced knowledge to understand thoroughly. It may be briefly stated thus:—In all revolving bodies there is a position, somewhere between the centre and the outside, where the total weight of the moving body may be said to be concentrated. In the beater, for instance, there is the weight of the shaft, the boss, the arms, and the blades; and while these component parts are revolving at the same speed, the surface speed or velocity is different in each, and, as a consequence, their capacity for storing energy varies. Now it is quite possible to conceive a point between the blade and the centre where the total weight might act, so that the total energy resulting from this position would equal the energy of all the various portions added together. This position is usually called the centre of gyration, and it is not a difficult matter to see that the heavier three-bladed beater will have its centre of gyration further from the centre of the shaft.

This results in a higher surface velocity, which increases the force of the blow in the proportion already shown. To neutralise this action the speed of the three-bladed beater is generally reduced, while in some machines it is both run at a slower speed and made of a larger diameter than the two-bladed machine. It is an easy matter by varying the conditions to make the action of each form of beater practically alike, and, as a matter of fact, in most cases the advocates of the respective beaters think them the best, because the conditions under which each is working are bound to result in giving nearly identical results.

It is almost unnecessary to point out, after what has been explained above, that the greater part of the difference of opinion is the result, to a large extent, of a misconception of the principles involved. At the present time the three-bladed is decidedly in favour, and deservedly so. It lends itself to variation of speed more readily, and its slower speed is a very important feature in its favour. It possesses practically all that can be claimed for the two-bladed form, at the same time working without vibrations, and being easily and perfectly balanced. The opening and cleansing actions of the beaters are derived from the rapidly repeated blows striking the cotton away in small tufts and dashing them against the grate-bars, which are arranged for about a quarter of a revolution, and, starting near to the feed, the dirt is driven out between them and falls into a suitable chamber. It may be remarked that the chambers into which the dirt from the openers and scutchers is deposited require frequent cleaning—once a day, at least, being necessary.

The percentage of waste in the scutcher varies according to the class of cotton, but about 1 to 2 per cent is the

usual amount. An improvement has been effected recently in the direction of making the beater perform a species of combing action, which ensures the cotton, as it is delivered to it, being thoroughly broken up. Lumpy or stringy cotton is almost eliminated by this means, and, as a consequence, the work of the card is relieved considerably. Fig. 40 shows a section through the beater referred to. It consists of three arms in sets; wooden lags containing

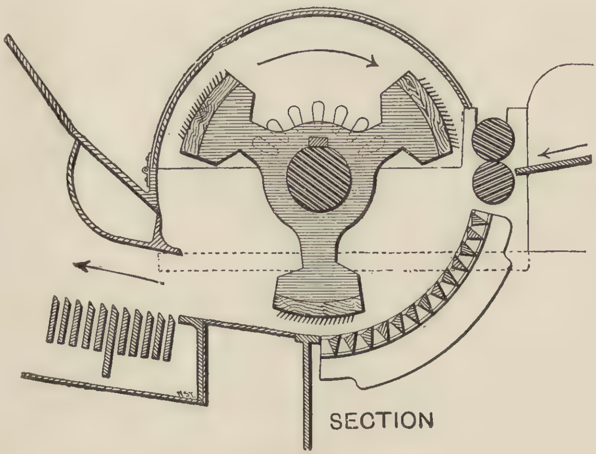


FIG. 40.

steel tempered pins are fixed to these arms; the pins can be varied, both in length and number, according to the work required of them. Their action in taking the cotton from the roller is clearly seen in the sketch, and there is no doubt whatever of its superiority, in opening the cotton, over the ordinary form. Its cleansing power is, however, deficient in the dirtier classes, as its combing action has not the effect of dashing the material against the grate-bars to the same extent that the bladed beater has.

The cages are generally arranged so that the top one is the larger of the two, with the object of permitting the current of air to drive the cotton upon it. The bottom cage is left comparatively free, so that dust and very fine fluff can fall upon it and be taken on to the dust chimney. The top cage also serves this purpose of carrying away the fine impurities that are sufficiently loosened to enter the cage through the wire or perforations. This arrangement of the cages has another advantage of even greater importance. If the cotton were deposited equally on each cage there would be two layers, and although they are combined in going between the cages, a strong tendency always exists to separate, especially when being unrolled behind the card. On leaving the cages (Fig. 41) a pair of cage feed-rollers A conduct the cotton forward to the lap end. This feature of all modern scutching machines is rendered necessary because of the loose condition of the fibres preventing the perfect separation of one layer from another if made into a lap when in this state.

To overcome this difficulty the cotton is passed between heavily-weighted rollers B, C, D, and E, called calender rollers. In this way the fibres are pressed into a more level condition. On leaving these rollers it goes forward, and is wound round what is called a lap roller. This roller is weighted heavily by a friction arrangement, and rests upon two large fluted rollers F and G, whose revolution causes the lap roller to revolve, and in doing so it winds on the sheet of cotton as it comes from the calender rollers. The lap, as a consequence, is very compact. When the lap is made of the required weight, say 30 lb., it is usual to have some device on the machine to automatically stop the feed part. An arrangement for this purpose is given in Fig. 37, and belongs to that feature in mechanics known

as the Hunter Cog. The length of the lap, or, what is the same thing, the weight, depends upon the number of revolutions of the bottom calender roller E. On the end of this

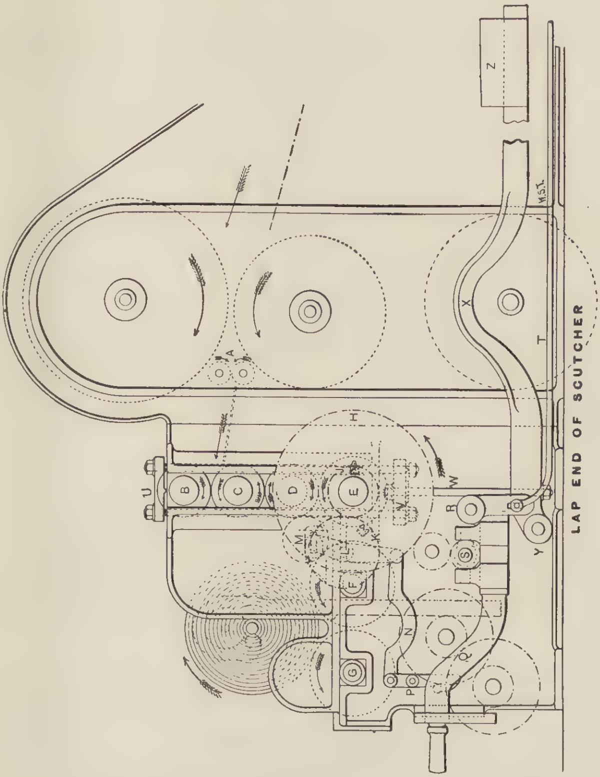


Fig. 41.

roller is a wheel J (43 teeth), gearing into a wheel K (various, 62 as a rule), mounted on a lever whose fulcrum is at M. The number of teeth in J and K is so arranged that the same teeth in each wheel come together only after

a definite number of revolutions of E. A projection is made on one wheel and a recess on the other, in such a manner that when the same teeth come into gear again the projection, fitting into the recess, moves the wheel K out of gear; the lever L, upon which K is mounted, is connected by a link N to a catch lever P; the movement is communicated to this lever and releases the catch, and thus permits the drop lever Q, whose centre is at R, to fall. In doing so the wheel S, which drives the bottom calender roller, is taken out of gear and so stops the lap end. At the same time a projection on the drop lever Q has connected to it a rod T, which by means of levers put the catch box out of gear on the feed pedal rollers, and so the feed of the machine is also stopped. In starting another lap it is simply necessary to lift the drop lever, when everything is put back ready for working again. This sketch also shows the weighting arrangement of the calender rollers, as much as 1500 lb. pressure being attainable with the weight usually sent with the machines.

It is as well at this point, before passing on to the gearing, to say a few words on the fans and the current of air they produce. The whole subject, however, is very vague, and little has been done from which we can determine beforehand the result of any given set of conditions. Experience points to the fact that a large fan running slowly gives better results than a smaller one running much more quickly. A remarkable feature, in this connection, is the low efficiency of the fan, for its work is of a light character, and yet its size and speed would seem qualified for performing a much more difficult operation. The efficiency never exceeds 30 per cent, and is often as low as 10 per cent. This means that the fan is only capable of doing from 10 to 30 per cent of useful work.

With this ignorance prevailing, it is not surprising that a large amount of haphazard work is the result.

Fans are generally made with straight vanes or arms, although this is contrary to the principle underlying its action. The reason for the practice is said to be the cheapness in making them, and also that the inertia (or weight) of the air can be ignored. Neither one nor the other are satisfactory reasons, especially when we know that the successful working of an opener and scutcher depends to a large extent on the action of the fan. The outlet to the fans, or the passages along which the air is forced after leaving the machine, must be of a form calculated to allow perfect freedom for the moving air. Sharp corners, abrupt turnings, narrow passages, etc., must be avoided; if not, complications ensue, such as back-pressure, chopping of the air, and partial neutralisation of the fan's action.

Introduction to Gearing Calculations

In entering upon a consideration of the gearing of cotton machinery, we are brought in contact with several of the most important methods of driving which the science of mechanics presents to us. They occur both in simple and compound forms, and are occasionally of such an apparently complicated nature as to acquire a more advanced knowledge of mechanics than the more elementary forms of gearing demand. As the reader's knowledge progresses it will be found that calculations form a very important element in the various processes, in order to bring the cotton from the bale into good yarn; so to make the calculations as clear as possible, an introduction of the

principles involved in their working will be made, together with worked examples.

When two circular discs are pressed into contact with each other on their circumference, the friction between them will cause one to drive the other, if the two are equal in diameter they will move equally, so that a revolution of one circle will result in a single revolution of the other circle, and a movement of any portion of the circumference of one will equal a similar portion of the circumference of the other; from this we obtain two equalities; namely, equal revolution, or as it is termed, equal angular velocity, and equal surface speed.

It will be noticed that if calculations were made in connection with the two circles, we should require to know the circumference of the circles—to get this, all diameters must be multiplied by 3·1416, a number that is of the greatest importance to us; when this number is turned into a vulgar fraction of a simple nature we have it expressed as $\frac{22}{7}$, and in this form it proves very serviceable both on account of its simplicity and its adaptability as an aid in cancelling.

If the circles have notches cut in their circumference at equal distances, and the resulting projection of one made to fit or gear into the recesses of the other, we obtain toothed wheels which drive each other not by friction but by leverage. The method of calculation, however, remains unaltered in regard to the dependence on the circumference, for when wheels are in gear the same number of teeth on each wheel occupies equal lengths on their surfaces.

Instead of having to work out the circumference of wheels, pulleys, etc., advantage is taken of the fact that 3·1416 is the common multiple of all diameters, and

consequently it is usually left out of consideration, and the number of teeth or the diameter itself used instead.

As an illustration take the following: Suppose a wheel 12 inches diameter on the pitch line is divided by a wheel 6 inches diameter:

The circumference of 12 in. $= 12 \times 3{\cdot}1416 = 37{\cdot}6992$
" " 6 in. $= 6 \times 3{\cdot}1416 = 18{\cdot}8496$

$$\frac{37{\cdot}6992}{18{\cdot}8496} = 2 \text{ (\textit{Answer}).}$$

By arranging the figures as follows: $\dfrac{12 \times \cancel{3{\cdot}1416}}{6 \times \cancel{3{\cdot}1416}} = 2$

It will be seen that 3·1416 cancels out, as they neutralise each other, and it is unnecessary to go through long

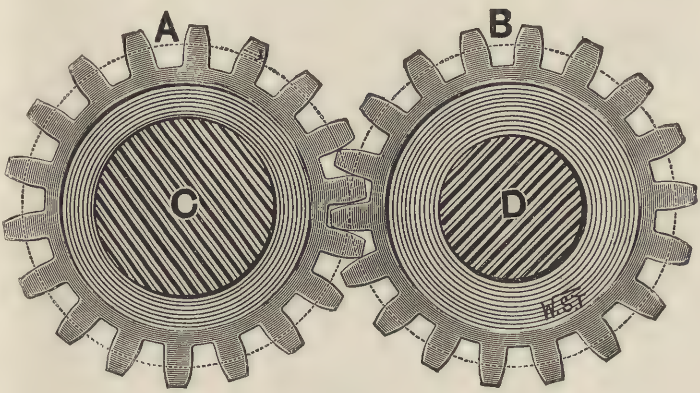


Fig. 42.

multiplication and division, as is done in the first case, when the result can be obtained in a much more simple manner.

In Fig. 42 we have a simple form of gearing consisting of two wheels A and B. If both wheels have the same number of teeth it follows that each will revolve equally,

but suppose A is the driving wheel and has forty teeth, whilst B is the driven wheel with twenty teeth, then if A turns once round, its forty teeth must have geared with forty teeth of B, but B's twenty teeth are insufficient in one revolution of itself, so it follows that more than one revolution of B has been performed. The exact number is found by dividing the forty teeth of A by the twenty teeth of B; this equals $\frac{40}{20}=2$, so that for one revolution of A, B will revolve twice. If expressed in letters as a formula we should write $\frac{A}{B}=2$; if expressed as a rule it would be: The speed of A multiplied by the number of its teeth, and the product divided by the number of teeth in B, equals the speed of B.

When B is the driver we have a small wheel driving a large one; so, as above, we divide the driver by the driven, which is $\frac{B}{A}=\frac{20}{40}=\frac{1}{2}$. This result means that A with forty teeth would only make half a revolution, whilst B with twenty teeth made a complete one.

Any number of individual wheels, each on its own axis, placed between A and B would not alter either of the above calculations; they would simply change the direction of rotation if arranged in odd numbers.

Fig. 43 presents us with a combination of wheels A, B, C, and D, and it will be noticed that C and D, introduced between A and B, are not on their own separate axis, but are on the same centre, and connected together, so that if one is moved the other moves also. Suppose A is the driver, then A drives D, and it will be noticed that C is driving B, so C is also a driver. D and B are simply driven wheels. If we proceed as before we should take these as two separate simple trains, but they are easily combined; for instance:

$$\frac{A}{D} = \text{speed of D and } \frac{\text{speed of D} \times \text{teeth in C}}{\text{teeth in B}} = \text{Speed of B}$$

This latter is expressed better when by using $\frac{A}{D}$ for the speed of C we get $\frac{A}{D} \times \frac{C}{B}$ = speed of B for one revolution of A.

An examination of this shows us that A and C the drivers—are multiplied together, and their product divided

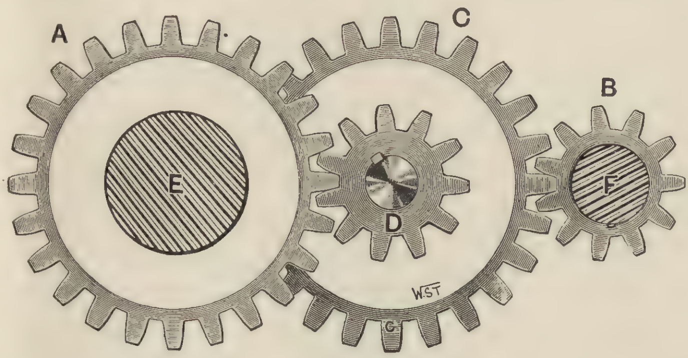


Fig. 43.

by D multiplied by B, which are driven wheels. In other words we have multiplied the drivers together and divided by the driven wheels multiplied together.

It is imperative that in addition to the above method of finding the revolutions, we should know how to obtain the surface speed of any roller that is on the same axis or shaft as the wheel; to do this we must know the diameter of the roller as well as the number of teeth in the wheel; we can readily find its revolutions, if the circumference is therefore multiplied by this, the surface speed is obtained.

For purposes of draft we frequently want to know how much quicker the surface speed of one roller is than another; this is done by finding the surface speed of each, and dividing one by the other. Example:—In Fig. 43 let $A = 40$ teeth; $D = 15$; $C = 30$; $B = 20$; the diameter of the roller $E = 1\frac{1}{2}$ in., and diameter of $F = 1$ in., the problem is to find how much quicker or slower the surface speed of F will be compared with that of E. A will be the driver.

First find the revolution of B for one of A.

$$\frac{A \times C}{D \times B} = \frac{40 \times 30}{15 \times 20} = \frac{1200}{300} = 4 \text{ revs. of B.}$$

Next find the surface speed of E.

$$1\tfrac{1}{2} \text{ in.} \times 3{\cdot}1416 = 4{\cdot}71.$$

The surface speed of $F = 4 \times 1 \times 3{\cdot}1416 = 12{\cdot}56$ in. Now $\frac{12{\cdot}56}{4{\cdot}71} = 2{\cdot}66$, so that the surface speed of F is 2·66 times quicker than E, or there is that much of a draft between them.

The above is a long process, but it is the foundation of the method generally adopted. It is usually expressed as a formula where instead of working out each step as above, the whole is combined as follows:—

$$\frac{A \times C \times \text{diam. of } F \times 3{\cdot}1416}{D \times B \times \text{diam. of } E \times 3{\cdot}1416}$$

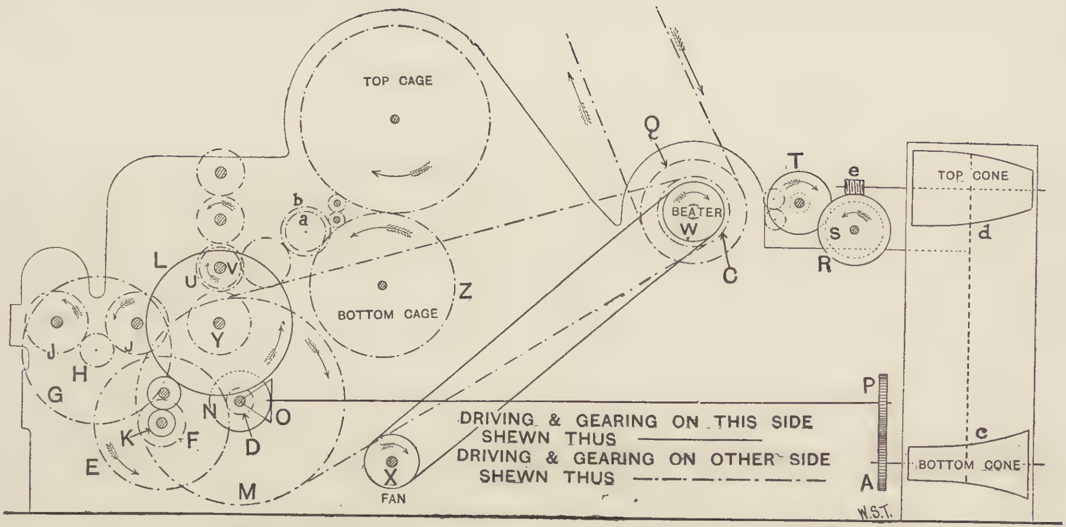
This can be made more simple by cancelling out the 3·1416; the worked example by the formula is now given:

$$\frac{40 \times 30 \times 1 \text{ in.}}{15 \times 20 \times 1\frac{1}{2} \text{ in.}} = 2{\cdot}66$$

which is the same result as found above.

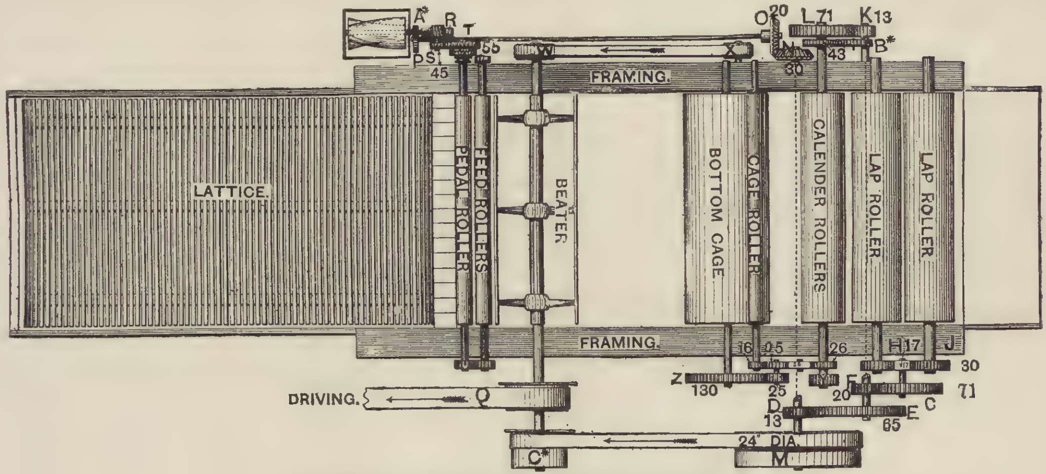
When a single worm is introduced in any gearing arrangement, it must be considered as a wheel with one tooth, if a double worm, as two teeth. When dealing with driving by belts, we proceed as above; but instead of teeth being used, the diameters of the pulleys are used in their place.

We will now devote some space to the subject of the driving and gearing of the scutcher. It is a phase of the subject with which all who are connected with cotton spinning ought to make themselves thoroughly familiar, not only in this particular machine, but in all the machines used in the process. It is also one which demands a little more mental development than a mere knowledge of the construction of the machine. It is not to the credit of those in authority that hitherto calculations relating to our subject have been presented in a form that proves only too clearly the poor opinion writers have of the extent of their readers' arithmetical knowledge, yet, even with the low standard it has been necessary to adopt, only a small percentage are found capable of profiting thereby. The requirements for the higher success in the examinations in cotton spinning, in the insistence of a knowlege of Applied Mechanics, is having a wonderful effect in raising the standard of our students, and of those in positions where a practical knowledge and its application is absolutely essential. This is the class to which the arrangement of the rules and calculations will most directly apply. Those of our readers unacquainted with the form in which they are given will be materially assisted by the table of wheels which accompanies them. But at the same time they are strongly advised to join classes, or to study the matter, so as to gain a knowledge of methods of calculations which will dispense with much



ELEVATION OF GEARING OF SCUTCHER

FIG. 44.



PLAN OF GEARING OF SINGLE SCUTCHER.

Fig. 45.

of the rule-of-thumb work and the puerile style of calculating that is in vogue to a great extent at the present time.

In order that the following calculations can be easily followed and understood, two drawings, Figs. 44 and 45, are given, each one complete in itself. The first one gives the driving and gearing as seen in elevation, each side of the machine being represented by a different type of line. The latter drawing (Fig. 45) is a plan view, looking on the machine from above, and shows the disposition of the gearing very clearly as regards the relative positions of the wheels side by side. The same reference letters are used in both diagrams, and allusion to them in the rules will be made, not by their names, but by the various letters applied to them. From drawings like the ones shown, anything relating to the speeds can be readily found, and very little difficulty will be experienced in applying the principle employed to other makes of machines than the one illustrated.

It will be observed that the direct driving of the scutcher takes place through the beater, Q being the pulley used for this purpose. On the same end of the beater shaft is a pulley C driving a large pulley M at the lap end. The shaft of this pulley practically dominates the gearing of the machine; the wheel D on it drives the entire lap end and cages, while the wheel N on the other end of the shaft transmits the necessary movement to the feed part. The machine as a whole can be run quicker or slower by changing the speed of the beater only, but portions of the machine can have their speeds altered to almost any extent by a change in the gearing at the point desired. The following table is given to enable the necessary calculations to be made :—

			No. of Teeth.
A	Bottom cone drum wheel changes the draft .	24-52, usual	24
B	Hunter cog wheel changes length of lap, various .	usual	62
C	Beater end pulley changes time of making lap, various	usual	7 in.
D	Bottom cross shaft wheel		13
E	Large wheel on drop shaft		65
F	Driving pinion for lap rollers		20
G	Compound carrier for lap rollers		71
H	,, ,, ,, ...		17
J	Lap or shell roller wheels		30
K	Drop shaft wheel		13
L	Bottom calender large wheel		71
M	Lap end pulley	diam.	24 in.
N	Driving bevel for regulating side shaft . . .		30
O	Driven ,, ,, ,, . . .		20
P	Regulator shaft wheel, 20-48 teeth . . .	usual	48
Q	Beater pulley, various, 12-16 . . .	usual	13 in.
R	Worm-wheel		65
S	Worm-wheel pinion		45
T	Catch-box wheel		55
U	Second calender wheel		21
V	,, ,, driving cages, etc. . . .		26
W	Beater pulley to drive van, various . . .	usual	7 in.
X	Fan pulley, various	usual	7 in.
Y	Bottom calender small wheel		27
Z	Bottom cage wheel		116
a	Compound carrier driving cages, etc. . . .		33
b	,, ,, ...		25
c	Bottom cone drum, various diams. . . .	middle	$5\frac{3}{4}$ in.
d	Top ,, ,, . . .	middle	$7\frac{1}{4}$ in.
e	,, ,, worm		Single
	Diameter of lap roller		$8\frac{3}{4}$ in.
	Diameter of pedal		$2\frac{1}{4}$ in.
	Revolutions of beater, various . . .	say	1000

Since the beater is the starting-point in our calculations, it is advisable to know definitely its speed. This can be obtained in two ways, either by calculating it from the main line shaft and through the counter shaft, or by using an indicator. The use of the indicator is the readiest and best method, even when a watch is necessary, but by means

of an indicator called "the Tachometer" the exact revolutions per minute of the beater are ascertained instantly without using a watch. This instrument is of inestimable benefit to the authorities in a mill, speeds from 300 to 12,000 being its usual range.

The speed of beater from the line shaft is found as follows:

(1) $$\frac{\text{Revs. of line shaft} \times \text{drum on line shaft} \times \text{drum on counter-shaft}}{\text{Pulley on counter shaft} \times \text{pulley on beater}} = \text{revs. of beater.}$$

$$\text{Ex.} \quad \frac{250 \times 32 \times 27}{18 \times 12} = 1000 \text{ revs.}$$

(2) $$\frac{\text{Rev. of line shaft} \times \text{line-shaft drum} \times \text{counter-shaft drum}}{\text{Revs. of beater} \times \text{dia. of counter-shaft pulley}} = \text{beater pulley Q.}$$

$$\text{Ex.} \quad \frac{250 \times 32 \times 27}{1000 \times 18} = 12 \text{ inches.}$$

The driving pulleys on shafting are generally called drums—the driven ones being known as pulleys.

To find the revolution of the pedal roller—

(3) $$\frac{\text{Revs. of } Q \times C \times N \times P \times c \times e \times S}{M \times O \times A \times d \times R \times T} = \text{revs. of pedal roller}$$

$$\text{Ex.} \quad \frac{1000 \times 7 \times 30 \times 48 \times 5\tfrac{3}{4} \times 1 \times 45}{24 \times 20 \times 24 \times 7\tfrac{1}{4} \times 65 \times 55} = 8{\cdot}73 \text{ revs. per min.}$$

The above is based on the principle of multiplying all the driving wheels together and dividing the product by all the driven wheels multiplied together.

To find the length of cotton fed to the scutcher, the above product must be multiplied by the diameter of the pedal roller and by 3·1416, or $\frac{22}{7}$

$$\text{Ex.} \quad \frac{1000 \times 7 \times 30 \times 48 \times 5\tfrac{3}{4} \times 1 \times 45 \times 2\tfrac{1}{4} \times 3{\cdot}1416}{24 \times 20 \times 24 \times 7\tfrac{1}{4} \times 65 \times 55} = 61{\cdot}7 \text{ in. per min.}$$

To find the total draft of machine, obtain the surface speed of feed roller, and divide it into the surface speed of the delivery roller. In the scutcher with which we are

dealing, the pedal roller and lap roller correspond to these parts. The surface speed of the pedal roller can be found from (3), while the following will give that of the lap roller :—

(4) $$\frac{\text{Revs. of } Q \times C \times D \times F \times H \times \text{dia. of lap roller} \times 3{\cdot}1416}{M \times E \times G \times J} = \text{surface speed of lap roller.}$$

Ex. $$\frac{1000 \times 7 \times 13 \times 20 \times 17 \times 8\frac{3}{4} \times 22}{24 \times 65 \times 71 \times 30 \times 7} = 267{\cdot}5 \text{ in. per min.}$$

If (4) is divided by (3) we get the result as follows :—

(5) $$\frac{D \times F \times H \times O \times A \times R \times T \times d \times \text{dia. of lap roller}}{E \times G \times J \times N \times P \times c \times e \times S \times \text{dia. of pedal roller}} = \text{draft.}$$

Ex. $$\frac{13 \times 20 \times 17 \times 20 \times 24 \times 65 \times 55 \times 47\frac{1}{4} \times 8\frac{3}{4}}{65 \times 71 \times 30 \times 20 \times 48 \times 5\frac{3}{4} \times 1 \times 45 \times 2\frac{1}{4}} = 4{\cdot}3 \text{ draft.}$$

This result can be obtained in another way. Assume the pedal roller to be the driver, and that it makes one revolution; then by multiplying the drivers together and the driven together until we get to the lap roller, and dividing them, we shall get this formula—

(6) $$\frac{T \times R \times d \times A \times O \times D \times F \times H \times \text{dia. of lap roller}}{S \times e \times c \times P \times N \times E \times G \times J \times \text{dia. of pedal roller}} = \text{draft.}$$

The top line indicates drivers, bottom line driven wheels, and when the number of teeth and diameters are substituted for the letters, the result gives a draft of nearly $4\frac{1}{2}$.

Ex. $$\frac{55 \times 65 \times 7\frac{1}{4} \times 24 \times 20 \times 13 \times 20 \times 7 \times 8\frac{3}{4}}{45 \times 1 \times 5\frac{3}{4} \times 48 \times 30 \times 65 \times 71 \times 30 \times 2\frac{1}{4}} = 4{\cdot}3 \text{ draft.}$$

There are two draft wheels, A and P, so that if a draft wheel is required for a certain draft, one of these wheels must be assumed; then work as follows if A is wanted—

(7) $$\frac{T \times R \times d \times A \times O \times D \times F \times H \times \text{dia. of lap roller}}{S \times e \times c \times P \times N \times E \times G \times J \times \text{dia. of pedal roller}} = A.$$

Ex. $$\frac{55 \times 65 \times 7\frac{1}{4} \times 4{\cdot}3 \times 20 \times 13 \times 20 \times 17 \times 8\frac{3}{4}}{45 \times 1 \times 5\frac{3}{4} \times 48 \times 30 \times 65 \times 71 \times 30 \times 2\frac{1}{4}} = 24 \text{ teeth.}$$

If P is wanted, then—

(8) $$\frac{T \times R \times d \times A \times O \times D \times F \times H \times \text{dia. of lap roller}}{S \times e \times c \times \text{draft} \times N \times E \times G \times J \times \text{dia of pedal roller}} = P.$$

Ex. $$\frac{55 \times 65 \times 7\frac{1}{4} \times 24 \times 20 \times 13 \times 20 \times 17 \times 8\frac{3}{4}}{45 \times 1 \times 5\frac{3}{4} \times 4{\cdot}3 \times 30 \times 65 \times 71 \times 30 \times 2\frac{1}{4}} = 48 \text{ teeth.}$$

To find the speed of fan—

(9) $$\frac{\text{Revs. of beater} \times W}{\text{Dia. of fan pulley}} = \text{speed of fan.}$$

Ex. $$\frac{1000 \times 7}{6} = 1166 \text{ revs.}$$

(10) $$\frac{\text{Revs. of beater} \times W}{\text{Speed of fan}} = \text{dia. of fan pulley.}$$

Ex. $$\frac{1000 \times 7}{1166} = 6 \text{ in. dia.}$$

To find the percentage of waste in scutcher—

(11) $$\frac{\text{Weight fed} - \text{weight delivered} \times 100}{\text{Weight fed.}} = \text{percentage of waste.}$$

Ex. $$\frac{100 - 98 \times 100}{100} = 2 \text{ per cent.}$$

To find the length of lap, take a length of several yards (say 5) and weigh it; then—

(12) $$\frac{\text{Weight of full lap} \times 5 \text{ yds.}}{\text{Weight of 5 yds.}} = \text{length of lap.}$$

Ex. $$\frac{30 \text{ lbs.} \times 5 \text{ yds.}}{3 \text{ lbs. } 2 \text{ oz.}} = 48 \text{ yards.}$$

The usual draft is 3 to 5, being generally equal to the number of laps doubled.

To find the velocity of bottom cage—

(13) $$\frac{C \times D \times K \times Y \times V \times a \times \text{dia. of } Z \times 3{\cdot}1416}{M \times E \times L \times U \times b \times Z} = \text{surface speed of cage Z.}$$

Ex. $$\frac{7 \times 13 \times 13 \times 27 \times 26 \times 33 \times 16 \times 22}{24 \times 65 \times 71 \times 21 \times 25 \times 116 \times 7} = 204{\cdot}3 \text{ inches.}$$

When an alteration is desired in the production of the

machine, the pulley on the end of the beater-shaft, which is driven from the counter-shaft, must be changed; if a smaller one is put on, the production will be increased, whilst a larger one would give us a reduced output.

If the production for any given pulley is known, it will be an easy matter to find the production when a change is made, as it is a simple case of proportion.

For instance, if a 7 in. pulley gives 12,000 lbs.

Then a 6 " " $\frac{12{,}000 \times 7}{6}$

$$\therefore \frac{12{,}000 \times 7}{6} = 14{,}000 \text{ lbs.}$$

It is sometimes required to alter the weight of the complete lap without altering its hank; to do this the wheel B is changed, a difference of one tooth making the lap heavier or lighter by the amount of the circumference of the bottom calender roller.[1]

The hank of the lap is also changed occasionally; when this is done the bevel wheel O is altered as required by the method of simple proportion.

Ex.: If a 20's bevel gives a lap of 12 ozs. to the yard,

Then a 24's " " $\frac{12 \times 20}{24}$

$$\therefore \frac{12 \times 20}{24} = 10 \text{ ozs. to the yard.}$$

The hank of a lap can also be altered by means of the draft wheels A and P in a similar manner to the above.

The following table represents the usual practice in regard to the weight per yard of laps from opener and scutcher when different classes of cotton are used:—

[1] The weight of a lap can be found by multiplying the weight of a yard by the revolutions of the bottom calender roller into its circumference. (The number of teeth in wheel B represents the number of revolutions.)

Cotton.	Opener.	Scutcher.
	Per Yard.	Per Yard.
Sea Island . .	13 ozs.	8 to 10 ozs.
Egyptian. . .	14 to 16 ozs.	10 to 11 ozs.
American . } Indian . . }	16 ozs.	13 to 14 ozs.

In order to facilitate calculations it will not be out of place to give briefly the method adopted of denoting the weights or measures in the cotton industry.

The table used for weighing is a combination of avoirdupois and troy weight, by this means the grains of the latter system enable very delicate differences in weights to be made.

TABLE OF WEIGHT

24 grains	=	1 dwt.	0 grains	
$109\frac{3}{8}$,,	=	4 ,,	$0\frac{3}{8}$,,	= $\frac{1}{4}$ ounce
$218\frac{3}{4}$,,	=	9 ,,	$2\frac{3}{4}$,,	= $\frac{1}{2}$,,
$437\frac{1}{2}$,,	=	18 ,,	$5\frac{1}{2}$,,	= 1 ,,
7000 ,,	=	291 ,,	16 ,,	= 16 ,,

TABLE OF MEASURE

54 inches	= 1 thread		
4,320 ,,	= 80 threads	= 1 lea	
30,240 ,,	= 560 ,,	= 7 leas	= 1 hank = 840 yards

An explanation of this table is desirable. A hank is the name given to the number of 840 yards there may be in a pound of lap, sliver, or yarn; if there is just 840 yards in a lb. the hank is one, if 12×840 yards the hanks will be 12s. and so on, so that if we know the weight of any given length we can easily deduce from it the hanks. It is not advisable in actual practice to measure off 840 yards of a lap, or sliver, or even yarn, so a shorter length is taken, and by means of a simple proportion sum we deduce the required hanks.

We can see from what has been said that if 7000 grains is divided by the weight of one hank (*i.e.* 840 yards) we shall get the hanks. Now when a smaller length than 840 yards is taken, for instance 120 yards, we only need divide by $\frac{1}{7}$ of $7000 = 1000$ and by taking a smaller length still the dividend will be proportionately smaller.[1]

To save working out the hanks when short lengths are taken, the dividends in the following table may be used according to the length weighed :—

Yards.	Dividend.	Leas.	Dividend.
1	8·3	1	1000
2	16·6	2	2000
3	25·0	3	3000
4	33·3	4	4000
5	41·6	5	5000
6	50·0	6	6000
7	58·3	7	7000
8	66·6	...	...
9	75·0	...	...
10	83·3	...	...
15	125·0	...	...
20	166·0	...	...
30	250·0	...	...
40	333·3	...	...
60	500·0	...	...
80	666·6	...	...
120	1000·0	...	...

[1] For instance if 840 yards weigh 7000 grains.

Then 1 yard weighs $\frac{7000}{840}$ „

$$\therefore \frac{7000}{840} = 8{\cdot}33 \text{ grains.}$$

So that if 1 yard weighs 8·33 grains we can find the hank by dividing

CHAPTER VI

CARDING

UP to this point we have dealt with processes whose objects have been to loosen the matted condition of the fibre and to drive out or eliminate a class of impurities which may be considered as foreign to itself; for instance, leaf, stalk, husk, broken seed, sand, etc. These are generally known as heavy impurities, and we have seen that a very severe treatment has been necessary in order to separate them from the bulk of the cotton. If, however, we examine a finished lap as it comes from the scutcher, we shall find that, in spite of what has been done, it is far from being satisfactory. A casual glance will show us that some of the heavy impurities are still mixed up with the cotton, their retention having been aided by an entanglement of fibres sufficient to have prevented centrifugal force driving them out. A closer investigation, moreover, will also disclose a state of things that it is important should be thoroughly realised if a comprehensive idea of carding is to be obtained. A few of the various appearances presented to us in this examination will be given, some of them, of course, requiring a microscope for their detection.

(1) *Small Masses of Stained Fibres.*—These result from several causes—moist foreign matter getting into the open pod and staining it; moths using the pod as a depository

it into 8·33, which equals one; or if the weight of a yard equals 12 ozs. or 5250 grains, we can obtain the hank in the same way by dividing it into the 8·3 opposite one yard in the table: $\frac{8\cdot 3}{5250} = \cdot 0015$ hank. When two or more yards are taken, the dividend into which the weight must be divided is increased as shown.

for their eggs, which ultimately produce caterpillars; in passing through the gin seeds are crushed, the oil of which stains the cotton considerably; wet cotton, when packed, develops mildew, and stained cotton is the result.

(2) *Broken Fibres.*—The best-arranged gin will produce broken fibres, but a badly-set one does enormous damage in this respect. Opening and scutching is responsible for much of it. Many fibres are naturally weak and easily broken, and though their breakage is an accidental occurrence it is an advantageous one, as they are easily eliminated and prevented from reducing the strength of the yarn with which they would otherwise have been incorporated.

(3) *Short Fibres.*—Apart from broken fibres, there are a number of short fibres which are taken from the pod and grow close to the seed. Much of it is of a downy nature; all the fibres do not arrive at perfection at once, and these may be described as fibres which would be perfect if allowed a little longer to develop.

(4) *Immature Fibres.*—Over-ripe and under-ripe fibres are present. All pods contain a proportion of each. The former are dried and shrivelled, while the latter are full length, but have been plucked just before their walls have collapsed and the accompanying twist been given them through this action. Twist is therefore absent, and their cross-section is cylindrical. Dead plants, caterpillars, and insects prevent development of portions of a pod. The fibres are, as a consequence, imperfectly developed and brittle, lacking all the essential features of a perfect fibre.

(5) *Nepped Cotton.*—Small entanglements of fibres firmly knotted together, and incapable of being unravelled, are formed principally in the gin.

(6) *Crossed Fibres.*—The whole lap comes under this head. All the fibres are arranged in a mass, and kept together by

an accidentally and loosely woven condition of crossing and recrossing in every imaginable direction.

All the above-mentioned conditions, while being natural to the cotton, are decidedly against its use for the making of yarn. Hence the importance of the next operation, called carding, which practically frees the cotton from these imperfections, must be apparent, and upon its success in doing this depends the success of all future operations in the cotton mill.

Carding, like all the other processes in spinning, has grown from very primitive forms. Its evolution has, however, been very rapid, so that the steps in its development can be easily traced. It is unnecessary to do this here; for our present purpose it is sufficient to state that each improvement made has kept in view the one principle of separating each individual fibre and combing it in such a manner as to free it from both its foreign and natural impurities.

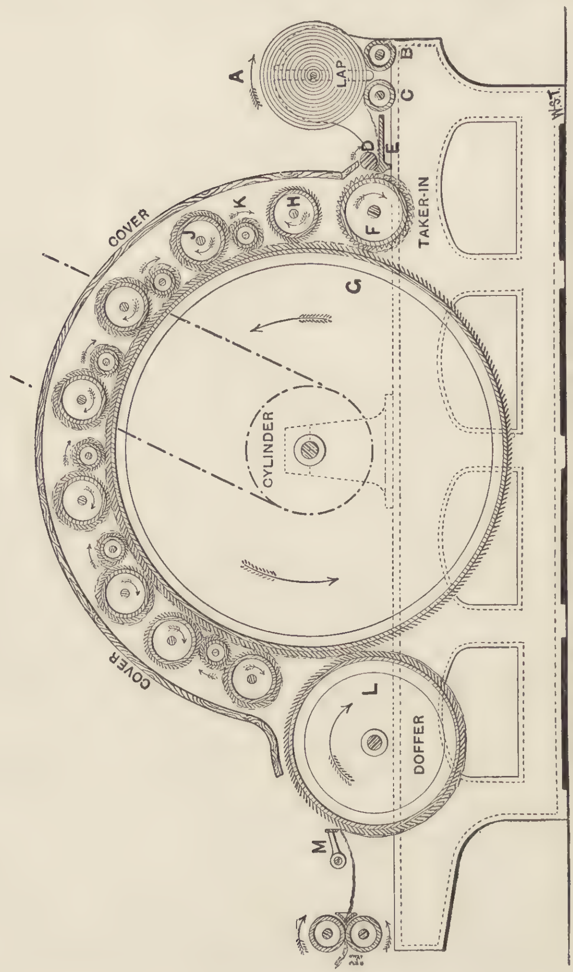
Innumerable patterns of cards were made twenty or thirty years ago, but to-day practically only one form survives, and is used throughout the cotton-spinning industry to the exclusion of all others. (This remark, of course, does not apply to waste spinning.) As many old mills are still using the cards that have worked for a good number of years, it will be as well to give a general idea of their form, and a description of their operations. Three types of machine will therefore be taken in order to give a clear view of the subject, and while the two older cards—the roller and clearer, and the stationary-flat or Wellman card—will be treated briefly, the card of to-day, known as the revolving-flat card, will receive a thorough examination and be fully illustrated.

The Roller and Clearer Card

The lap is taken from the scutcher and placed in the position shown at A, Fig. 46. It is the usual practice to rest it upon one or two wooden rollers B and C, when the friction caused by its weight enables it to be unrolled as the rollers revolve. On going forward it passes between a weighted feed-roller D and a dish plate E. Directly it emerges from these, a quickly-revolving roller covered with saw teeth, and called the taker-in (F), takes it round and brings it into contact with a large cylinder (G) covered with thickly-set wire, whose greater surface speed enables it to transfer the cotton to itself. The fibres now carried round are next brought into contact with a number of pairs of wire-covered rollers called rollers and clearers (J and K). In passing these a combining action is set up, which has a tendency to isolate the fibres and consequently clear them of their impurities. The first one or two rollers (H) are so arranged to serve the purpose of clearing a quantity of dirt from the cylinder, and are known as dirt rollers, though it must be understood that all the rollers perform the same function to a greater or less extent. After passing about half-way round the cylinder, a smaller and comparatively slow-moving cylinder, called the doffer (L), is met with. Upon this are deposited the carded fibres in a condensed form; from this they are taken by means of a quickly-vibrating comb M, and after being gathered together and passed through a funnel, go forward between a pair of rollers N to the coiler.

In order that a better idea of the special action of the roller and clearer may be obtained, a supplementary drawing, Fig. 47, is given. As the cylinder, with a surface speed of about 1600 ft. per minute, carries the fibres of

cotton round in the direction of the arrow, the inclination

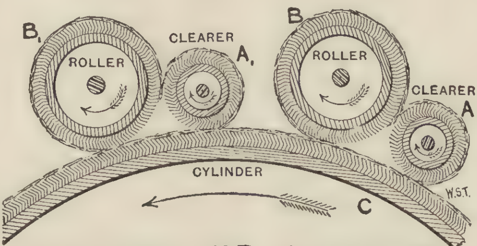


ROLLER AND CLEARER CARD

Fig. 46.

of its wire points will enable it to keep the fibres on its

own surface until some obstruction meets them. In passing the small roller or clearer A, whose surface speed may be about 400 ft. per minute, the cotton will naturally go forward uninterruptedly, especially as the wire teeth of A are inclined away from the direction of the motion of the cylinder. The revolution of A, although slower and in the same direction at their point of contact, aids the passage of the cotton, and if there were any cotton on the surface of H the quicker speed of the cylinder would easily take it forward. On arriving at the roller B, however, an obstruction is met with in a double form—first, its



ROLLER AND CLEARER

Fig. 47.

teeth are inclined against the direction of the cylinder; and, secondly, their movement is slow—about 20 to 30 ft. per minute.

Now suppose a small entangled mass of cotton comes round to this point; it is held by the teeth of the cylinder, and in passing B would be caught by the teeth of the roller. One of three things will now happen. Either the entanglements of the cotton on the cylinder teeth will yield, and in doing so will be combed out; or the entanglements on the roller teeth will yield and consequently be combed; or neither will yield, and so the small mass will

be torn asunder, the cylinder and roller each taking its own piece.

In the first case the cotton held by the roller B will be carried round until it meets the clearer A, whose teeth will easily free those of B from its fibres, and, as we have shown, these will in their turn be taken again by the cylinder as it passes A. This smaller entanglement is now in the same position as the entanglement of our second supposition, and they will go through more or less the same treatment in passing each roller until the doffer is reached.

We are now in a position to see the defects in this form of card. On looking at Fig. 47 it will be noticed that the roller B is almost in contact with the cylinder at what is practically a point. The teeth of B on either side of this point leave the cylinder, so that the fibres of cotton in passing have only two or three rows of teeth to meet them and help in combing them out. Such a small surface of teeth easily permits large quantities of the smaller entanglements to pass forward without being acted upon, and in this condition they are totally unfit for good work. This evil is aggravated by the fact that small as the working surface is, yet it is only repeated at intervals of 9 or 10 in. round about one half of the cylinder. The enlarged sketch shows very clearly the passage of the cotton. It must be observed, though, that the cotton on the roller or worker B is entangled cotton which its teeth have retained. The cylinder has not deposited it there in the same way as the cotton is deposited on the doffer, the speed of B being altogether too slow for that purpose.

The last remark must be thoroughly understood before leaving this part of the subject—First, because it is the essential feature of the machine, and secondly, because

several writers have presented it in their descriptions in a manner that has conveyed the impression that the clearer has the cotton deposited on it in the same way as the cylinder deposits the fibres on the doffer. If this were the case, as some writers state, no carding whatever could take place at this point, exactly in the same way that no real carding or combing can take place between a cylinder and doffer. Again, when the clearer takes the cotton from the roller, carding is also entirely absent, the fibres are attenuated in respect to each other, if they are loose enough to permit it, because of the greater speed of the clearer, but an entanglement on the teeth of the roller or worker remains an entanglement on the teeth of the clearer, and there is no action whatever between the two rollers that can possibly comb or card out an aggregation of fibres, any more than the cylinder can comb out any entanglement of fibres that may exist on the teeth of the taker-in. The very weakness of the card lies in the fact that such a small number of teeth are presented to the cotton as the cylinder carries it past the clearers. It is owing also to this that the roller and clearer card was almost always used for the rough work of the breaker card in double carding, and at present its use in the spinning of waste and low numbers permits a production where quantity occupies first place and quality is scarcely necessary.

The Revolving-Flat Card

We will now proceed to treat of the revolving-flat card, and, as this card will be dealt with very fully in detail, it is advisable at present to give merely an outline of its form as well as a general idea of its operations.

For this purpose a diagram (Fig. 48) is given, showing its chief features, and the following description will assist in conveying a knowledge of the process.

The lap A is placed upon a slowly-revolving roller B, and is unwound through the friction produced by its own weight. From here the sheet of cotton passes over the smooth surface of the dish-plate C, and on between the curved portion of this plate and the feed roller D. The slow revolution of this roller (about 7 inches per minute) brings the cotton into contact with the saw teeth of the quickly revolving taker-in E ($9\frac{3}{4}$ inches diameter; surface speed, 1000 feet per minute). It receives a very effective cleaning at this point, and the loosened fibres are carried round to the large wire-covered cylinder F, whose surface speed of double the amount enables it to take them to itself and carry them forward. Surrounding almost one-half of the cylinder F is a series of what are generally termed flats, G, set very close to the wire of the cylinder, and covered also with similar teeth. Their movement is extremely slow (about 4 inches per minute), and in the same direction as the cylinder. They offer, therefore, a large and almost stationary combing surface to the fibres of cotton as they are brought round, and give this machine an immeasurable advantage in its cleaning power over the previous machine. The carded cotton is now transferred to the doffer H ($24\frac{3}{4}$ inches diameter; surface speed about 78 feet per minute), from which it is stripped by the comb J, and after the resulting web is gathered together at the calender rollers K, it is taken on and placed in the coiler L by suitable mechanism.

In dealing with the details of the card, the first feature to receive attention will be the feed part. Formerly it

consisted simply of two feed rollers, which carried the

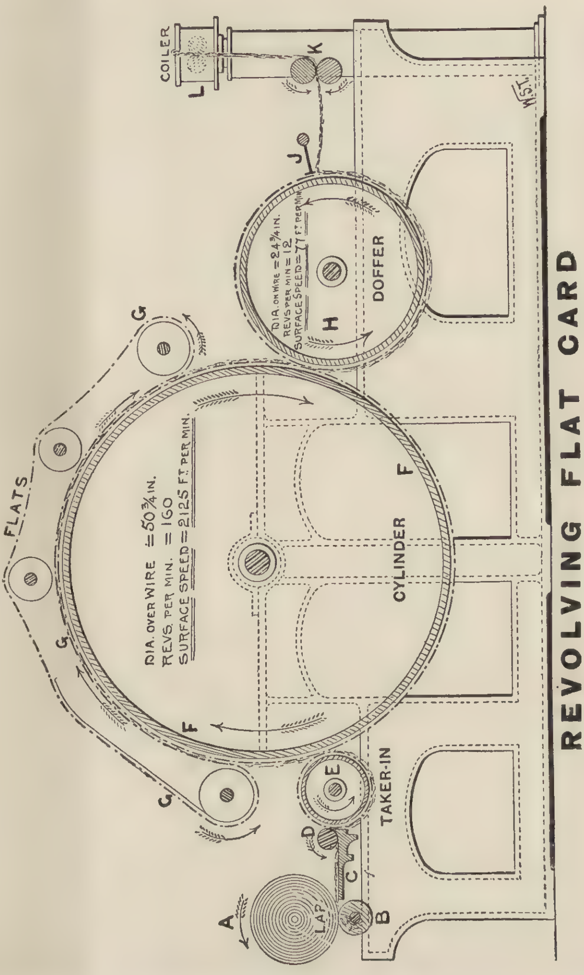


Fig. 48.

cotton forward and presented it to the taker-in, as seen

in Fig. 49; but now this arrangement is practically dispensed with. At the same time it will be instructive to examine into its action, and see where the fault lies that prevents its utility. We had occasion, when treating of the scutcher feed, to point out the disadvantage of feed rollers for short-stapled cotton; for a similar reason their unsuitability for the card can be shown. Not only so, but by taking into account the combing action of the taker-in, we shall also see their unsuitability for any kind of cotton, either long or short staple.

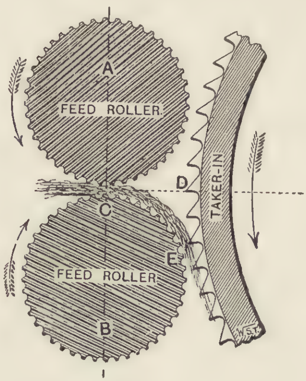


FIG. 49.

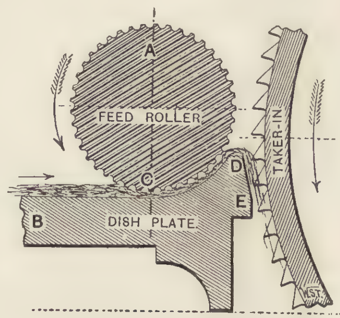


FIG. 50.

In the sketch the feed rollers A and B are $2\frac{1}{4}$ inches diameter. A vertical line through the two centres gives us their point of contact C, and therefore the point where the lap in passing through is gripped. From this point to the teeth of the taker-in (which just clears the feed roller) will be about $1\frac{1}{16}$ inch. The fibres, on being fed by the rollers, do not stand out horizontally between the two, but are delivered along the curve of the bottom one. The distance in this case from the grip C to the striking point E of the bottom feed roller will be about

$1\frac{1}{2}$ inches. Under these conditions it would be absolutely impossible for fibres to be combed by the teeth of the taker-in, and at the same time be held by the two rollers, instead of this the cotton would be taken away in lumps, and masses of entangled fibres would be presented to the cylinder by the teeth of the taker-in. If smaller rollers were used the evil would be reduced to that extent, but rollers of the minimum diameter, consistent with strength, would always contain the serious fault of having the grip too far away from the taker-in teeth, and consequently result in the prevention of the combing action, which is such an important factor in this part of the card. The above difficulty is now overcome by the almost universal practice of using what is termed a dish feed, a section of which is given in Fig. 50. Here we have the bottom feed roller taken away, and in its place is substituted a polished plate B, curved upwards at that part where it comes under the feed roller A. The immediate result of this is to move the points where the cotton is held from C to D. In other words, the cotton is brought almost to the teeth of the taker-in, so that directly it emerges at D it comes under their combing action, and since the fibres as they come forward are arranged in every imaginable position relative to each other, we can easily see that the teeth of the taker-in, as it passes through them, will effect a thorough combing before they have moved along the surface E of the dish plate a sufficient distance to free themselves.

A point to be carefully understood in respect to this is, that if some fibres are lying in the lap with their length in the same direction as the length of the roller, they will simply be struck away at once by the taker-in, whilst those lying crosswise will be partially combed and

then freed from the grip of the roller and plate according to the amount of their cross position. This leads up to the fact that only those fibres whose length lies in the same direction as the moving lap, and which are delivered to the taker-in, end on as it were, will receive the greatest amount of the combing action. A very small percentage of the fibres of a lap, however, occupy this position, so that from these considerations, as well as by a reference to the remarks previously made on the inequalities present in the mass of the fibres themselves, we are compelled to recognise that the cotton is not detached from the dish feed as separated individual fibres except occasionally, but rather in very small groups or tufts.

This probability from the above reasoning is rendered almost a certainty when we remember that no matter how close the taker-in is brought to the dish feed, there will be a portion of the cotton between the grip D and the teeth which will be taken forward directly it is free without being combed. Fig. 51 is presented in order to give an idea of the effect of the taker-in teeth in passing through the cotton. We can see that the fibres are arranged in nearly parallel order, and almost individually isolated; but to prevent a misconception arising that all the fibres, or even a majority of them, are detached in this condition, the drawing must be interpreted by the foregoing description. This appearance of the lap can be seen on any card if the feed roller be lifted out and the end of the lap that has projected through is examined. The position of the point on the surface E of the dish plate B, Fig. 50, where the average fibres are supposed to become free from the grip at D, is an important feature. The one used for short-stapled cotton will naturally have the point nearer to D than long-stapled cotton. To show this clearly sections of the dish plate for different

kinds of cotton are given in Fig. 52, and are used for the cottons there denoted. It will be seen that Indian cotton is freed very soon after coming under the action of the teeth, whilst the other cottons remain gripped for a longer period, according to the length of their staples. The point where they may be said to become free is emphasised by a

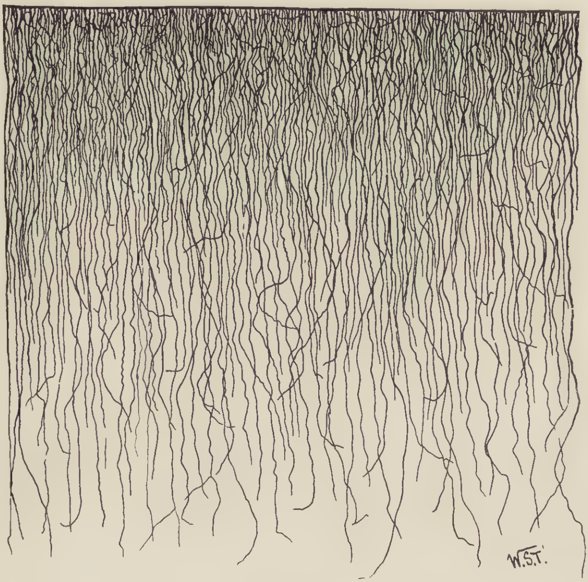


FIG. 51.

small spot in each of the sketches A, B, C, and D. In setting this part of the card in relation to the taker-in, it is advisable to exercise great care, for whilst very little damage can result to the fibres themselves, granted everything else is correct, a great deal of waste can be made, and very inefficient work be done, as well as a greater strain being put upon the other working parts of the card.

Having considered the feed arrangement in detail, we will now give a view of the immediate locality of this part of the machine in Fig. 53. The cotton is no sooner taken from the feed than it is carried past one or two bars C and D with sharp edges, known as mote knives. Large numbers

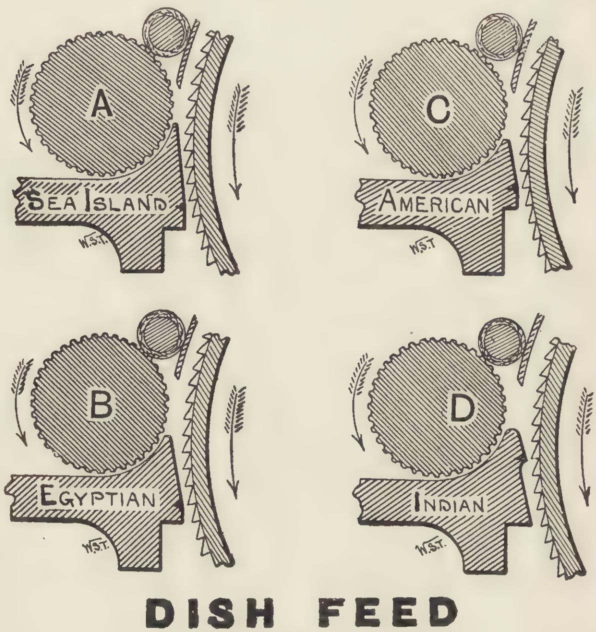
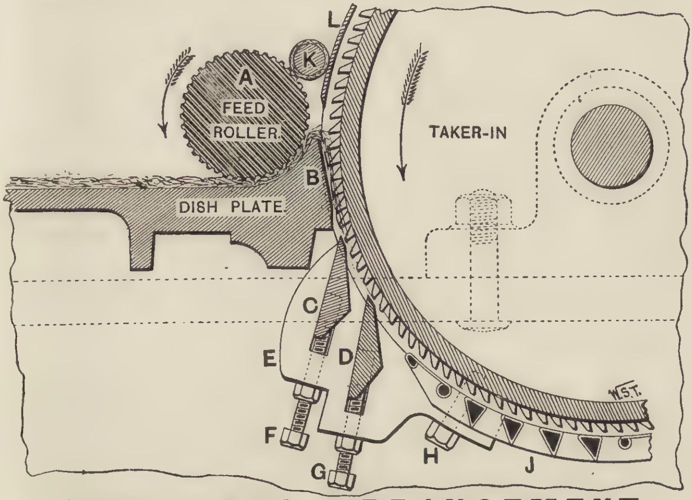


FIG. 52.

of what may be called unattached fibres are naturally easily caught by these bars, and so fall between their spaces. The same thing happens when the portions of seed, leaf, etc., are loosened. It is here where they are driven out, as freed from the tips and between the spaces of the saw teeth of the taker-in, where they are sometimes sticking.

There is very little, if any, necessity for varying the

angle at which the mote knives are set, so the drawing shows no arrangement for this purpose, but their adjustment in two other directions is essential. For instance, their correct distance from the teeth is obtained by means of the setting screws shown at F and G, whilst the interval between where the fibres are free from the feed part to the edge of the first mote knife C can be altered by unscrewing



DISH FEED ARRANGEMENT

Fig. 53.

the set screw H and sliding the bracket E (which carries both knives) round a circular plate that forms part of the pedestal of the taker-in; H is then used to securely fasten it in its new position. Following on from the mote knives in the direction of revolution we have a grid, or, as it is generally termed, an undercasing J, its object being to permit short, loosened fibres to fall out. It is hinged to a similar under-casing for the cylinder, and it is so arranged that on a

resetting of the card through wear of the wire it is capable of being adjusted to the new position. The cover L is a polished sheet of steel, covering in the whole of the upper part of the taker-in. An iron rod K, covered with flannel, is placed between the cover L and the feed roller A, and it serves a very useful purpose in taking up from the feed roller the dust and fluff or very short fibres which adhere to it. It also acts as a kind of draught preventer at this particular point.

In reference to Fig. 51, it was remarked as a kind of warning that the state of the fibres there represented, though actual, was only momentarily so. Very few fibres go forward to the cylinder in this condition; indeed, it is almost impossible for such a thing to happen. If individual fibres are detached, which can easily happen, because the feed roller is delivering them at the same time the teeth are combing them, they stand very little chance of reaching the cylinder. An examination of the waste from below the taker-in of any card will show that a proportion (and by no means a small one) of the fibres are of a good average length, which proves that the cotton, unless locked in the teeth, is in a position to be easily taken off with the slightest obstruction, or even by centrifugal force alone. (With under-casings well set and constructed, the above remarks would be much modified.) We can obtain confirmation of this view by looking at the teeth of the taker-in, and examining their disposition upon its surface. Figs. 54 and 55 represent the form of the tooth, and Fig. 55 the method of inserting it into the iron surface. Grooves are cut spirally from one end of the taker-in to the other.

The number of rows of teeth vary from 6 to 10 per inch, so that the pitch of a single spiral equals an inch, whilst the distance from one row to the next will vary

from $\frac{1}{6}$th to $\frac{1}{10}$th of an inch. By this spiral disposition of the teeth we obtain an unbroken line of points, because no two teeth can possibly follow each other in the same path during the revolution of the taker-in. The plan of a portion of the surface in Fig. 54 will show this about the natural size; but to make the matter clearer, an enlarged view is also given to the right in Fig. 56, when it will be seen that one tooth is followed by another tooth, which, however, does not strike the cotton exactly in the same spot as the first one, but is about half the thickness of its tooth on one

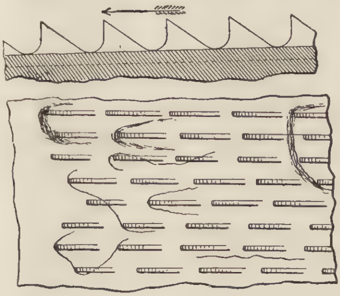


FIG. 54.

FIG. 55.

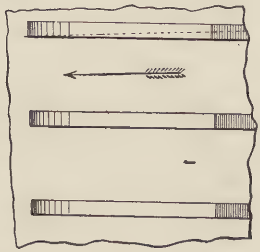


FIG. 56.

side, where eight rows of teeth are used to the inch, and 90 teeth are in the circumference of each row ($\frac{1}{90}$in. will represent this distance). In this way an increased probability of good combing by the taker-in is obtained. This especially will be recognised when it is mentioned that as many as two million teeth pass the dish feed whilst one inch of the lap is fed to them. The one inch of lap is calculated to contain about the same number of fibres, and at first sight it might be thought that there is some design in having the teeth and fibres equal; but although it represents the best experience on the matter, we are not at liberty to suppose that each fibre is provided with a tooth to carry it away. We

have already shown how this is quite contrary to actual practice, and there also seems to be no reason for the suggestion when an intelligent examination is made of its action.

Fig. 54 will give some idea of how the teeth carry the fibres forward. It will be understood that tufts are easily taken onwards, and the individual fibres, when locked in two or more teeth, are also easily carried to the cylinder; but when a fibre is free from, or on the tips of, the teeth, it is almost certain to be lost at the mote knives, or in passing over the under-casing. Of course the short fibres stand the best chance of becoming free enough to escape in this way.

The setting of the taker-in in relation to the dish feed requires a very careful adjustment. Two methods are generally adopted to obtain the necessary degree of exactness, both of which in their practical application suffer somewhat through carelessness. The first, and one that is still very extensively practised, and upon which great reliance is placed, is where the dish feed is brought sufficiently close to cause the revolving teeth of the taker-in to touch it. A hissing noise is produced when this happens. The dish feed is now moved back, leaving an interval between itself and the teeth which depends upon the judgment and experience of the man in charge. Considering the delicacy of the operation, and the very small distance concerned (from $\frac{1}{200}$th in.), it is not surprising to find how few men can set so that both ends are exactly alike, as $\frac{1}{1000}$th part of an inch out at either end probably means 10 to 20 per cent variation from the desired distance. This is bound to result in unequal work being thrown on the cylinder teeth—a state of things which is most undesirable both for the card and for the finished yarn.

The other method is one that is preferable in every way. It consists in moving the organs that are being adjusted together, and inserting between them a gauge in the form of a slip of steel, the thickness of which is definitely known, until it fits anywhere along the full width of the card. Exact settings can be obtained in this way, but a serious evil is often present in the gauges themselves. Almost all gauges, especially after being in use some time, get bent in their width, and instead of being perfectly straight, as at A, Fig. 57, they become shaped as at B and C, and consequently they touch at the points DEF in B and GHJK in C.

With the thinner gauges, B and C will straighten somewhat if a tight fit is obtained when setting, but from

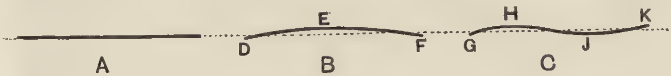


Fig. 57.

numerous observations and tests which have been made, it is found that the thickness marked on the gauge is always exceeded. The thicker gauges, such as the $\frac{1}{90}$th part of an inch, when bent as above, scarcely yield at all when used in setting, and a large percentage of error is consequently introduced. This error, however, is not one that produces inequality in the setting, like the previous method; for when gauges are used the distance across the face of any organ of the card is uniform, and so the wire is not worked unevenly. But the evil is still a serious one, and requires attention. Many faults experienced in the card may be traced to faulty setting and still faultier gauges. A considerable reduction in the possibility of error in a gauge might be made if the steel were split up

the middle, or even into three parts, the width remaining the same. This would prevent the distortion of the gauge, as the narrow width would not bend so easily as the full gauge would. Another way to overcome the difficulty would be to make three narrow strips of steel into the single width of an ordinary gauge.

The cotton, having been carried round by the taker-in, is brought into contact with the teeth of the cylinder, a distance of about $\frac{7}{1000}$th inch separating the two cylinders. The special form of the teeth, their large numbers, and the greater surface speed (cylinder, 2100 ft. per minute; taker-in, 1000 ft. per minute), enable it to take the cotton from the taker-in, and, if the fibres are sufficiently loose to permit it, a slight attenuation may take place at this point, otherwise the cylinder will take the cotton forward exactly in the same condition as it is presented to it, and this for the simple reason that the teeth of the taker-in offer no resistance whatever to this action; indeed, they rather aid the freeing of the cotton from their own surface, and allow of its transference to the teeth of the cylinder with a minimum amount of disturbance. Fig. 58 will make this apparent, and a still clearer view will be seen in the enlarged drawing, Fig. 59 (AB is a line joining the centres of the cylinder and taker-in, and serves this purpose for both sketches).

A consideration of the cylinder teeth may with advantage be made at this part of our subject. It presents a wide field for investigation, but we will try to confine ourselves to those features of which a knowledge is essential to a good understanding of its principles.

In the first place, the cylinder ($50\frac{3}{4}$ in. diameter on the wire and 40 in. wide) is covered with a very large number of wire teeth, there being almost four millions round its

entire surface. These teeth are embedded in a foundation of specially-woven materials, composed principally of mixtures of wool and cotton, and sometimes in a surface of indiarubber. The purpose of this foundation is to supply a holding power for the teeth, and at the same time

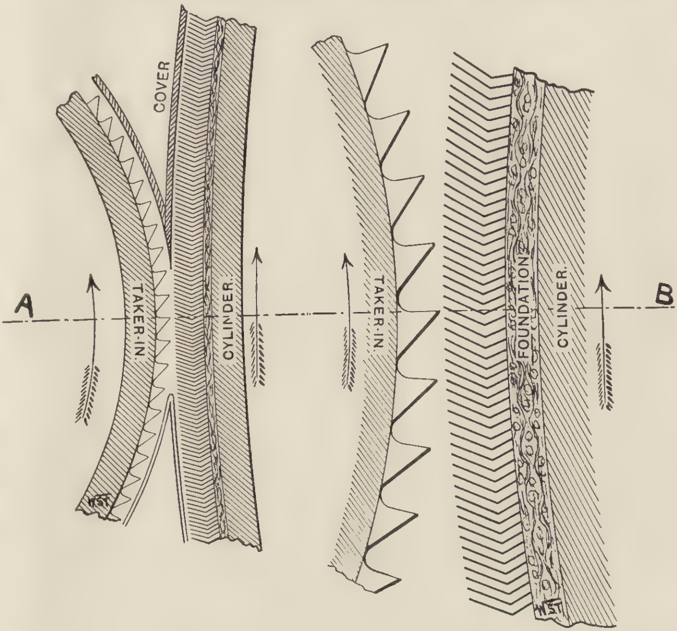


FIG. 58. FIG. 59.

to allow a certain amount of flexibility to exist. The teeth stand out from the foundation at such an angle as to give them power to carry forward any fibres to which they become attached. This function of the teeth presents a wide latitude for choice, and enables a variety of angles to be made, and, as a fact, scarcely two specimens can be obtained having the same inclination.

Fig. 60 represents an enlarged general view of the teeth fixed in their foundation. The surface of the foundation at G is frequently covered with a thin layer of rubber, the elasticity of which is intended to cause the wire to spring back into its original position whenever it has been deflected either by the grinding roller or by any other strain put upon it when working. The rubber is found to be susceptible to climatic conditions, and when these vary through a long range the heat produces a species of disintegration, so that care is necessary in deciding on the adoption of this kind of clothing.

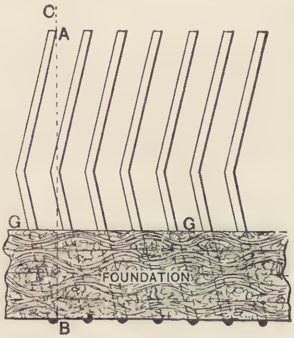


Fig. 60.

The arrangement of the wire points follows one of three systems shown in drawings Figs. 61, 62, and 63, which are

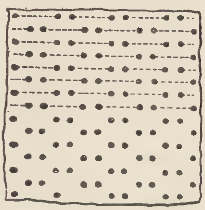


Fig. 61.

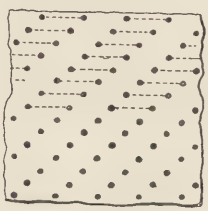


Fig. 62.

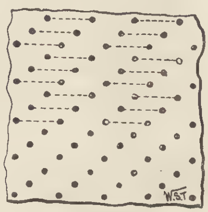


Fig. 63.

known respectively as "open set," "twill set," and "rib set." These names are given to them according to the method adopted of inserting the teeth in the foundation. As two teeth are composed of one piece of wire (the back of the wire is shown by the dotted line joining the teeth,

the dots representing the points, or, as they are called, the crowns) according to the number of points within a given space we get what is termed the counts of the wire—the higher the counts the more teeth there are in this given area.

If the card is being used for long fine cotton the number of teeth on the various organs must be greater than if coarser cotton is being worked, the reason for which is often presumed to be self-evident; but it is frequently overlooked that the better-class cottons are the weakest, and they therefore require more support whilst being carded than the poorer classes. And again, as they are used for a superior kind of yarn, it is necessary that a better cleansing action should be given to them. There is, however, no fixed rule on the matter, the decision as to the counts being generally left to the person responsible for the working of the card.

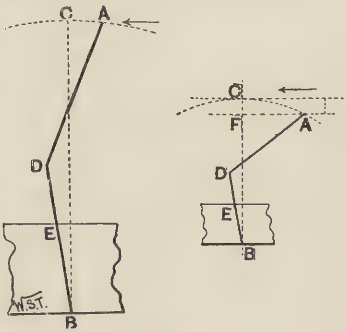


Fig. 64.

The clothing or filleting, as received from the makers, is in long, narrow lengths, and the fixing of it upon the cylinder, etc., demands extreme care. It must be perfectly level throughout, and as it is wound on spirally it must be so done as to have an equal tension throughout its entire length. Machines are now used that record this tension, and supply us with a means of regulating it to the requisite degree, so that blistering, etc., is almost a thing of the past. To secure it firmly in position, the cylinder is drilled

longitudinally at intervals, with rows of holes, and then plugged with hard wood. The clothing is nailed to these plugs, and upon the care and skill exercised in performing the whole operation depends the working quality of the machine, and also the length of time it is capable of doing this successfully before renewal is necessary.

A point that it is perhaps necessary should be understood in connection with the angle of the wire teeth is the position of A (Figs. 60 and 64) in relation to the vertical line BC drawn through the other end of the tooth B at the back of the foundation. Now it is not difficult to see that if something forces the point A from its position in the direction of the arrow, it will move it in what would be practically a portion of a circle having its centre at B. It is generally assumed that this centre is at E, where the wire leaves the foundation, but this is apparently a mistake, for the elasticity of the wire tooth is immeasurably greater than that of the foundation, which would yield considerably before the wire itself began to bend at E. If A corresponded with C, its movement along the circle would bring it away from any teeth that might be above it, and this we may say is a most desirable working condition; but from an analysis of a very large number of wires of various makers, it is quite an exception to find the point of A so well placed, its usual position being a little in advance of the vertical line, as shown in Fig. 64. This being so, it is quite obvious that any movement of A towards C would cause A to be raised a little, and to approach any teeth that might be placed above it. The evils supposed to exist in consequence of this are sufficient excuse for examining the matter a little further, and seeing if the supposition is one that might safely be ignored. An exaggerated diagram is given in Fig. 64, to which our remarks will apply. The

dimensions we shall use are, however, exact ones—BC = $\frac{3}{8}$ inch, AF = $\frac{1}{16}$ inch. This last distance is extreme, and is taken to test the distance that A would move vertically from the foundation in going from A to C. The problem resolves itself into finding the distance FC in a circle of $\frac{3}{8}$ inch radius described from the centre B. This works out as 0·0055 inch, which equals about the $\frac{1}{200}$th part of an inch. Very few cards are set, or can be set for the production of good work to this distance between the cylinder and the flats, so that the lifting of a tooth in the way suggested would appear to be of no serious consequence. Apart from the above reason, we may ask if it is possible for the tooth to be raised up under normal conditions of working when made as described above! When we reflect that it is only when the same entanglement of fibres is held by both the cylinder and flats that the necessary force to separate the fibres exists—which also tends to disturb the position of the point of the tooth—we shall see that the possibility of such a thing happening is very remote. Several teeth would of necessity be engaged on each side, and the firmness of any foundation in which they were embedded would effectually prevent the teeth yielding any more than the slightest distance; the entanglement would be pulled asunder before the teeth would move, and, if it so happened, the combined strength of several fibres would be found inadequate to overcome the resistance of the foundation to the movement of the tooth. Broken fibres would naturally be the result, and there is no doubt that broken fibres in the card are traceable to this cause. Even the chance of an entanglement occurring strong enough to move the wire is very small, and the possibility of this taking place, so that the flat teeth and cylinder teeth acted upon are directly over each other, is still so much more

remote that its damaging effect on the wire may be safely ignored.

Almost immediately after passing the taker-in, the cylinder brings the cotton to the point where the flats begin to enter upon their work. This is illustrated in Fig. 65, and as an aid to an explanation of the effect on the fibre of passing onward between the cylinder and the flats, an enlarged drawing is given in Fig. 66, which shows the relative position of these organs to each other. It will be

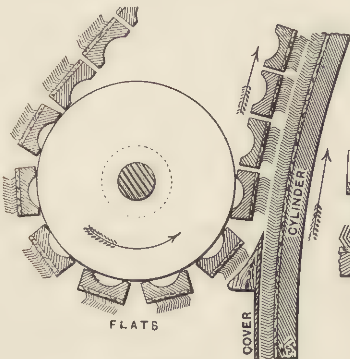


FIG. 65.

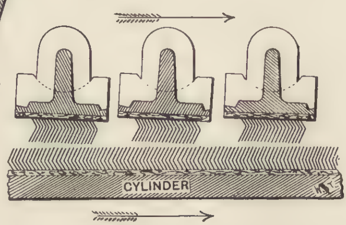


FIG 66.

noticed that the wire surface of the flats is not parallel to that of the cylinder, the two being wider apart at the point where the cotton enters, and nearer to each other where it leaves. This arrangement is generally termed the heel and toe, and its object is to effect a gradual carding at each flat. As the cotton is carried forward from one flat to the other several conditions tend to cause the fibres to rise a little from the surface of the cylinder as the space between each is passed. Currents of air, centrifugal force, and the elasticity of the fibres might be suggested as probable causes of this action. These raised fibres would be rather

severely dealt with if they were dragged instantly into the narrow space between the cylinder and flats; so this suddenness of action is avoided by making the entrance three or four times greater than the finishing space, and a gradual effect is the result. Small masses or entanglements are beneficially treated in this way, and eventually reduced to isolated fibres by the continued action from flat to flat.

The manner in which the cotton is carried forward may with advantage have a little attention devoted to it. We have already given a representation of the wire teeth, and from a consideration of the number of these teeth we should conclude that there were several ways in which they could carry the cotton onwards. For instance, if a small mass of cotton was penetrated by a few of the teeth, it would be easy for the cylinder to take them forward; individual fibres would be carried if they became locked or mixed up among several teeth; and, finally, fibres would be removed if one or more teeth caught them so that they doubled round, leaving the ends free and furthest away from the direction of motion. All these methods are in active operation in the card. The first, of course, could only exist for a moment at the first flats, when it would be broken up, and then partake of the action of the other two. The second method would be more applicable to the short fibres, as these would the more easily find their way into the teeth. Their accumulation in this way among the wires of the cylinder necessitates a frequent clearing to remove them. The longer fibres would only occasionally be able to lie with their full length locked as suggested; a free end would always admit of the possibility of the flat wire catching it and plucking it out.

The third method is the one that is paramount in good carding, for here we have the fibres doubled up, as it were,

and held anywhere from near the ends to the middle, by the wire, with the ends flying behind and being drawn through the superimposed wire of the flats. It is scarcely possible that many of the fibres maintain one position on the cylinder during a revolution, as they must be considerably disturbed in various ways in their onward movement. When entanglements occur they are certain to be caught by the teeth of the flats as well as the cylinder. The angles of the teeth of each enabled them both to maintain their hold, and as a consequence the collection of fibres is combed out by one or the other, or else it is pulled asunder, each taking its own portion. The cylinder's portion will be treated by the other flats, which will be passed; whilst the flat's portion may be caught by the cylinder again, and further reduced. This is only probable for very small entanglements, like neps, as close observation seems to show that when once they become entangled in the teeth of the flats they remain there. It will be understood, from the whole of the action explained above, that the greater portion of the carding will take place on the earlier flats. As these become charged they lose some of their cleansing power; but to compensate for this the fibres are very loose, and have not the same necessity for it as on their introduction. The flats, as they come round to the doffer end, leave the cylinder and return over the top of the card to the front again; in the meantime they are stripped of the waste that has accumulated in their teeth. An examination of this waste will show that it is almost all doubled on the holding teeth, the free ends lying in the direction of movement; and, further, if the flats are examined with the waste on them, they will be seen to have their surface very unequally covered by it, being very thickly coated in some places and almost bare in others. It is quite obvious from this that

the cotton is in a very irregular condition when taken by the cylinder, and considerable waste of good fibre is the result, as can readily be seen if the denser portions of the flats' waste are inspected. In doing this, care must be taken to open the fibres out in order to get their full length. At present it is apparently impossible to avoid what we have just pointed out, but fortunately it is only in the earlier flats where the evil exists. By the time the cotton reaches the ends of the flats, it has been opened out to such an extent that it would be an impossibility to strip it in the form of a web. It must not be supposed that this extreme looseness of the fibres is the result of the fibres being completely isolated and arranged in some kind of a parallel condition on the surface of the wire. A close view of the cylinder would quickly dispel this idea, and show that the fibres, although few to the square inch, are arranged crossing each other n all directions among the tips of the teeth. This may be accounted for partly by the well-known characteristic of the cotton fibre—when it is free to do so—to retain the twisted and distorted form it had when taken from the boll. Each fibre has probably been isolated and straightened out innumerable times in passing between the flats, but they are sufficiently elastic to return immediately to their original state, and when this portion of the operation is finished, they are found to lie very irregularly both in direction and condition.

We will now leave for a short time the further consideration of the carding action, and direct our attention to a matter which is bound up with the process with which we have just been dealing. Stress was laid upon the necessity of setting the flats very close to the cylinder (from $\frac{1}{90}$ in. to $\frac{1}{200}$ in.). Continuous working and cleaning of the wire teeth affect their working qualities, which can, how-

ever, be renewed by grinding the tips of the teeth. This grinding removes some portion of the length of the wire on flats and cylinder, and consequently the space between the two wire surfaces is increased. This is shown in the diagram Fig. 67. AB is the space required between for good working, but the grinding action has taken a portion off both flat and cylinder (this is shown black in the sketch), and the space then becomes greater, as seen at CD. It is imperative that AB should be constant; so to effect this the flat must be lowered until this space is obtained. In the previous portion of the subject a brief description was given of how the flats moved slowly forward over the upper part of the surface of the cylinder.

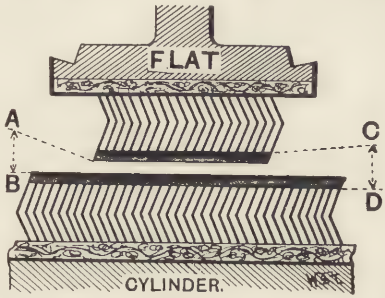


Fig. 67.

As the grinding operation affects every flat, it will be seen that they must all be lowered to the same extent and at the same time. To do this successfully, many devices have been adopted, ranging from very primitive efforts to some of the most remarkable instances of mechanical ingenuity. In order to cover the ground as completely as possible, all the important methods used by the principal machine-makers will be given as examples.

In order that the flats can be affected to the extent of lowering them bodily towards the centre, it is necessary that they should move upon some surface through which the requisite change can be made. This surface is generally termed the bend of the card, and, according to its character,

it may be termed a flexible bend or otherwise. The conditions which are imperative in a successful card in relation to the bend are—that it must be a perfectly smooth surface; that the flats moving upon it must also be perfectly smooth on their moving surface; the flexible, when once set, must remain unyielding so far as bending or deflection is concerned; and there must be every facility for setting the arrangement accurately and expeditiously.

Previous to the year 1880 the form of bend was similar

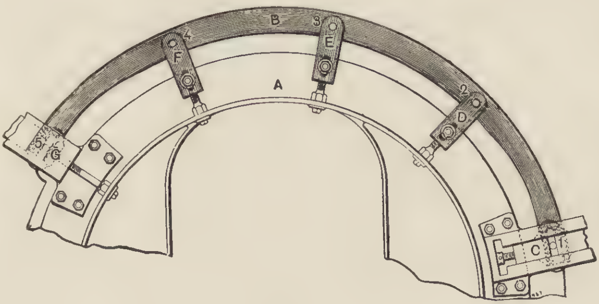


FIG. 68.

in principle to that shown in the illustration in Fig. 68. A framework A, forming part of the framing of the machine, had connected to it, by means of bolts and links, a segmental strip of metal surrounding its circumference for over one-third of the distance. The bolts which supported this surface were capable of adjustment, and as there were at least five of these supports for the flexible on either side of the card, the flats travelled on a fairly good solid surface. When the necessity arose for resetting and bringing the flats nearer to the centre of the cylinder, the adjusting screws drew the flexible down, and in doing so caused it to yield sufficiently to become a portion of a smaller circle.

This was done the more effectively by arranging the shape of the flexible in such a manner that the yielding would take place gradually on either side of its middle.

In some form or another, this flexible bend is still extensively used. Its disadvantage in the eyes of many is the necessity of setting each of the five points on either side separately. Considerable time is taken up in performing this operation; whoever does it must possess experience and exercise great care, and only very skilful workmen can be entrusted with the duty.

A more modern arrangement of this flexible is shown in Fig. 68, in which A is a circular portion of the framework of the machine, and B is the flexible upon which the flats travel. Five pins are firmly fixed at equal intervals along the flexible, 1, 2, 3, 4, and 5, and engage in brackets C, D, E, F, and G respectively. These brackets are bolted to the solid framing A, and are adjustable radially. When the card requires re-setting, the adjusting screws below each bracket are each in their turn operated upon, and the flexible is drawn towards the centre. It will be noticed that the centre bracket E has the pin 3 fitting it exactly, so that this point must follow the bracket in its movement; but the other brackets contain slots. The reason for this is apparent when we know that the flexible in its new position on a smaller circle occupies a greater proportion of the circle than it did in its old position, and consequently we find that the pins C, D, F, and G do not fall radially, but partake of a combined movement both circumferentially and radially, the slots being made in the brackets to permit of this being done.

Many people still prefer a card fitted with flexibles similar to the one just described, and it undoubtedly has its advantages, as well as being cheaper; but we are bound to

recognise the waste of skill, energy, and time which must be constantly going on in a mill containing them if a successful result is to be obtained from the machines.

Most of the principal makers of machinery, whilst still supplying this form of flexible when specially ordered, also make some improved form which partially or completely frees the cards from the faults hitherto associated with the flexible. Several of these will be given, and for our first example we take the one illustrated in Fig. 69. Here we

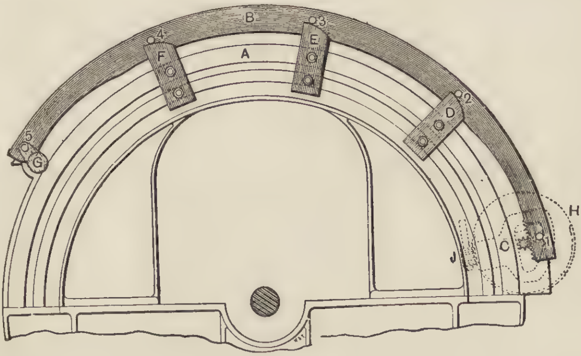


FIG. 69.

have the segmental flexible with five pins resting on supports. To lower it, a very effective and ingenious method is adopted. One end, 5, of the flexible B is connected to the end of a short lever G, having its pivot or centre on the circular framing A. Each of the supports C, D, E, and F are also firmly fixed to this framing, and are never disturbed. The other end contains a portion of a rack into which gears a small wheel; by turning the wheel the whole flexible moves downwards, and in doing so the pin 5 begins to travel round in a small circle in consequence of its connection with G, and in this movement it naturally approaches

the centre, but not radially so. The position taken up by 5 regulates the position assumed by the other pins, for they must all approach the centre to the same amount. The path they follow will not be circular, like that at 5, but will be a mixed curve resulting from this circular movement and their greater angular displacement on account of occupying a large proportion of the smaller circle as previously described. Fig. 70 is given in order to enable the description to be followed more easily. AE is the

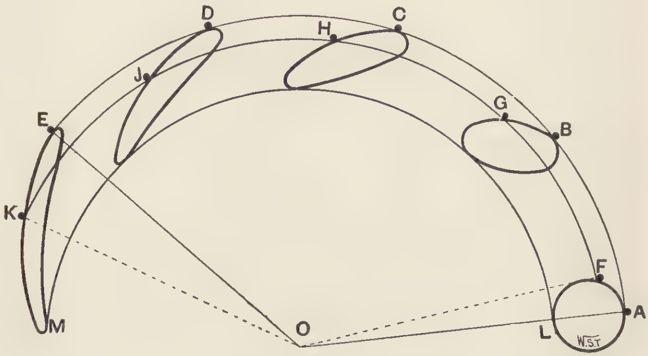


FIG. 70.

flexible in its first position, and A, B, C, D, and E denote the five pins. When A is turned round in the smaller circle it will occupy the position at F, which is nearer the centre, its angular movement having been AOF. It is clear that all the other pins must approach the centre to the same extent if the flexible is to be concentric, and it is also clear that the end E must move through a greater angle than A if the same condition is to be fulfilled; so a combined movement is the result, and as all the pins are affected for the same reason, but not equally so, it will follow that each pin would trace out a curve suitable for itself. If brackets are

made having surfaces similar to the curve, we can rest the flexible upon them, and be perfectly certain that it will be concentric whatever position it may occupy. The curves for the various points are clearly shown, and in order to show the effect of a complete revolution of the small lever G in Fig. 69, the complete curves are drawn out. It must be apparent that the flexible will require bending to the smaller circle, and so that this yielding during re-setting may be distributed equally over its whole length, it is shaped specially for that purpose.

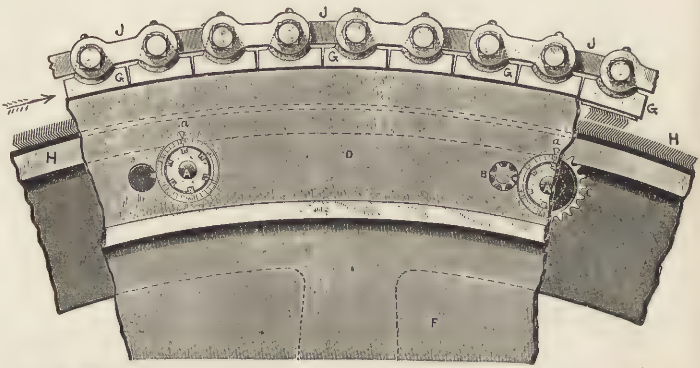
The great advantage of the above arrangement is that the whole of the five setting points are set simultaneously, and the amount of the setting clearly indicated. This is shown in the drawing Fig. 69. On the axis of the small wheel is fixed a large index wheel H, having teeth cut in a portion of its circumference; into this is geared a worm, J, and through this worm the flexible is moved, a finger indicating the exact amount. To prevent any one tampering with the arrangement, a lock can be applied to it.

It will be seen, from the sketches and description just given, that a flexible arrangement of this kind possesses superior advantages over the older form of five setting points. The setting of the whole of the flats is an operation of such a simple character that the possibility of damage through carelessness and loss of time in its performance is reduced to a minimum. The form of the flexible lends itself easily to the necessary amount of bending that is required in bringing it into a circle half an inch less in diameter than its original size, and the five supports upon which it rests afford a very firm foundation for the movement of the flats. The character of the concentricity depends entirely on these supports and the spiral curvature adopted in each; and provided these are made with

precision, there is nothing to prevent an almost mathematical exactness being obtained, especially considering the smallness of the curve that is actually used.

The next example of an improved form of flexible bend

FIG. 71.



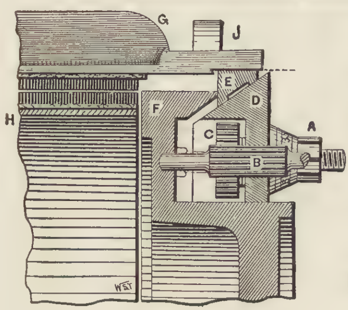


FIG. 72.

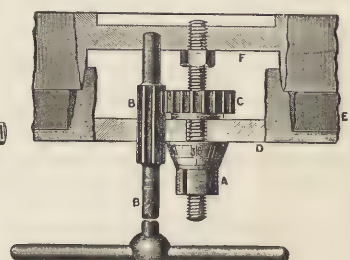


FIG. 73.

is represented in the drawings Figs. 71, 72, and 73, and is very successful in its practical application when there are taken into account the narrow limits within which it works. Its exactness to a very small fraction of an inch is undoubted, and for all practical purposes it is thoroughly

equal to the demands made upon it, both in its maintenance of concentricity and in its accuracy of adjustment. On this account it will be of interest to the student to observe that the principle underlying its action is not strictly mathematical—for the simple reason that the principle which enunciates that a straight inclined surface, sliding upon another inclined surface in the same plane, always moves parallel to itself, is not applicable to curves or curved surfaces of any description. (This is capable of easy demonstration, but, as already pointed out, the movement required is so small that the calculated variation is of a character so microscopic that it may be, and is, ignored.)

An examination will now be made of its arrangement and action, reference being made to the drawings. Fig. 71 gives an outside elevation of a portion of the flexible; Fig. 72 shows a section through its various parts; and Fig. 73 represents a sectional plan view.

The various parts may be enumerated as follows: H is the cylinder, over which the flats G travel; F is the general circular framing, which is firmly bolted to the card sides; D is a turned segment, capable of sliding upon a true concentric ledge of the framing F, so that, whatever position it occupies on this ledge, its concentricity is maintained. The upper surface of D is inclined, and upon this incline is supported an inclined segment E, upon which the flats G travel, E thus becoming the flexible. When it is desired to lower the flats, the inclined segment D is drawn out, and E will consequently fall and occupy a lower position. It is necessary that the flexible should bend in order to conform to the smaller circle of which it will now form a portion, and it is specially made so as to permit easily of this. The adjusting mechanism is not operated at one point, so that each of the five setting places on each side

of the card must be set separately. An improved method of doing this, however, renders the performance an extremely simple one: a screwed stud is firmly fixed to the framing F, and passes through the segment D, its outer end being fitted with an index nut A. On the inner side of D a toothed nut C is fitted on the screw, and by the manipulation of A and C any adjustment required can be easily obtained. In order to effect this setting, and at the same time to prevent interference therewith, a toothed key B is inserted through a hole in D, and gears with the tooth nut C; this enables C to be screwed up and locked against the face of the index nut A. When one point has been set correctly the number of the index is noted, and each setting place is adjusted to the same indication. It will be noted that, although there are five distinct setting places on each side of the card, only one of them requires care in setting, and even then the operation is of a most elementary character. The other nine operations are quickly performed, and the accuracy of the indices and the perfect manner in which the nuts and studs are made, ensure uniformity in the whole operation.

From Fig. 71 a good idea may be obtained of the method adopted in connecting the flats together. It consists of an endless chain J, each link swivelling upon a stud fixed firmly in the end of the flat G. The stud is screwed into a projection cast on the end of the flat, so that the chain comes immediately over the flexible bend E, Fig. 72. This position is important, and all modern cards adopt the same; the reason for its adoption being that the pull and weight of the chain cause a deflection of the flat if placed in any other position, and so disturbs the accuracy of the setting.

It is absolutely necessary that the chains on each side should be exactly alike, and should work with the same

tension, for the slightest variation would cause the flats to become twisted or crossed on the cylinder and their accuracy to be destroyed. To show how exact the chains are now made, it may be mentioned that in the whole length of the chain used the variation does not exceed one-fiftieth part of an inch from the standard.

Another feature that may be noticed in the drawing, Fig. 72 (which represents what is now the common arrangement of all cards), is the closeness of the cylinder H to the framing F. The opening is, indeed, so close that it may be almost considered closed, and the currents of air that were formerly such a serious cause of trouble are now practically eliminated. The cylinder can also be clothed with wire up to its end, and an appreciable increase in the working area is thus obtained, which means increased production.

The next arrangement to be described is one based on a principle entirely different from the preceding ones, and one that does not depend in any way on the flexibility of its support for success in maintaining a circular path for the traverse of the flats. Its main features are illustrated in the drawing Fig. 74. Instead of the usual flexible bend, a series of steel bands, A, about fifteen in number, varying in thickness from $\frac{1}{30}$th to $\frac{1}{100}$th of an inch, are used; and upon the uppermost of these the flats move forward. The surface on which they are placed is turned true to the centre of the cylinder, and they are kept in tension by means of their connection to the fixed pin B and the tightening screw C. Whenever the necessity arises for the lowering of the flats, one of the bands is removed, and a smaller circular is thus provided to compensate for the effect of grinding. If the removal of a band is too much for the purpose, it is taken off, and a thinner one is put in

its place, so that a much finer setting can be obtained than is represented by any single band. For instance if a $\frac{1}{30}$th band was withdrawn, and a $\frac{1}{40}$th one replaced it, the difference would mean an adjustment of $\frac{1}{120}$th of an inch. It is easy to see that this changing of the steel bands must result in considerable waste of time in a large mill, and the

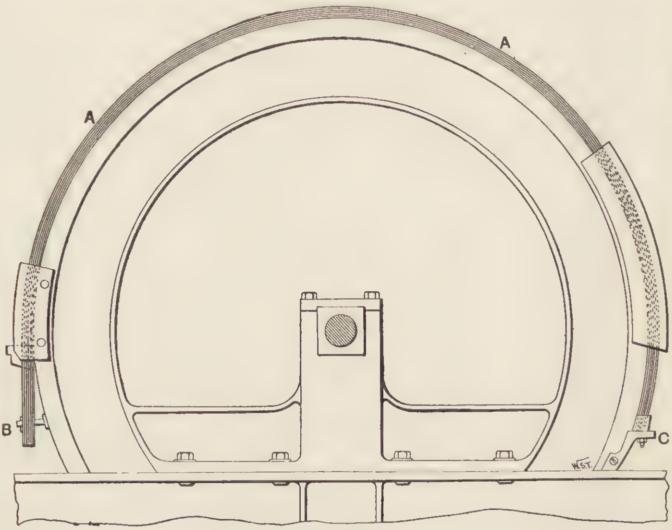


FIG. 74.

apparent advantages of the system would be counterbalanced by such a loss. To overcome this most decided objection a peculiar plan was adopted, which was a kind of compromise between leaving the adjustment as it was until sufficient grinding justified the removal of a band and an exact adjustment by changing to obtain the correct setting necessitated by the grinding. We will explain the method adopted by supposing grinding to have taken place,

and an adjustment to be necessary. This means that the flats are too far away from the cylinder. Now, instead of lowering the flats the required distance, the cylinder centre is raised by means of a regulating screw and index arrangement: as a consequence, the space between the flats and cylinder, which is vertically over the centre, is reduced to the necessary amount; but at the sides the vertical movement has not made any material change in their relative positions, and as a result concentricity is destroyed, and

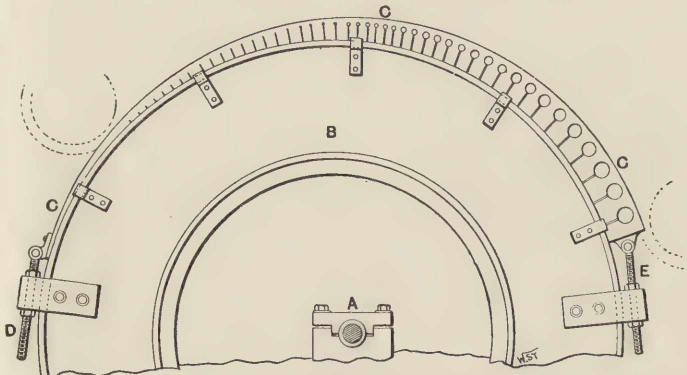


FIG. 75.

the card works under slightly unequal conditions on its surface. This is, however, of such a small amount that for practical purposes it may be disregarded.

In Fig. 75 an interesting form of flexible bend is shown, and we proceed at once to describe it, after which an analysis of its action will be made: A is the centre of the cylinder and B the circular framing. The upper surface of this framing is shaped as a portion of a spiral, and upon it is bedded the flexible C, which, of necessity, partakes of a wedge shape. This form is most unsuitable for obtaining the requisite amount of flexibility; therefore a series of

holes and saw-cuts is made in it, in order to permit of its bending equally throughout its length. The flexible is maintained in position by the adjusting screws D and E, and by their means the curvilinear wedge can be moved round the spiral. When this happens its surface naturally approaches nearer to the centre A, and the flats which travel upon it are regulated accordingly.

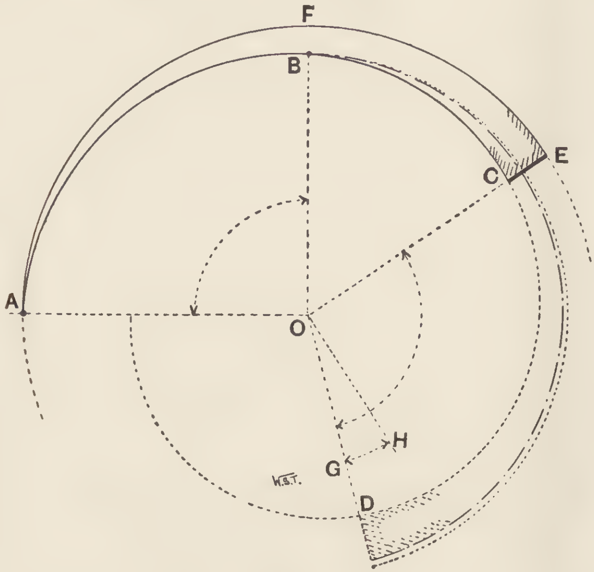


Fig. 76.

As before remarked, the small movement made by the flexible is taken advantage of by many, as affording a good opportunity of totally ignoring scientific principles in the construction of a flexible. This may be all right in its way, if the result is good practically; but in cases of this kind no claim can be sustained for them as regards mathematical accuracy. In the present example, which is

undoubtedly practically correct within the limits worked, we have a typical specimen, which, if judged upon the question of the principles involved, would be quickly condemned.

As it will be interesting to the thoughtful reader, a diagram is given in Fig. 76, so that an explanation may be made of its action. The drawing is, of course, exaggerated, but the reasoning will hold good. ABCD is the spiral framing, upon which rests the flexible ACE, the upper surface of which will be a true circle from centre O. If the end A of the flexible be now moved along the spiral framing through a right angle to B, it will have approached the centre a distance denoted by FB. During the movement of A, the other end C of the flexible must have moved along an equal length of the surface of the spiral, and its new position will be at D. The diagram clearly shows that its angular movement is greater than that of the end A, its excess over a right angle being represented by the angle GOH. This extra angular motion results in the end D falling nearer to the centre than the other end A, and, of course, concentricity is destroyed, the variation from a true circle when in its new position being shown in the diagram. What has been said in regard to a large movement is equally applicable to a smaller movement, and the demonstration of error can readily be made; but it is found to be too inappreciable to interfere with the general accuracy of practical working.

Another form of flexible is represented in Fig. 77. The flexible A has cast upon it four projecting pieces, which serve the double purpose of affording guides for its adjustment and serving as slides for the reception of eccentric bowls, which are used to obtain this adjustment. Upon studs fixed to the framing B, and passing through slots in the

projecting portions of the flexible, are mounted eccentrics C, to each of which is fixed a quadrant gearing into a circular rack, which is capable of a circumferential movement. The movement is brought about by a worm D gearing in a portion of the rack, and is such that when D is turned the rack causes each eccentric to revolve upon the fixed studs. This action lowers or raises the flexible according to the direction of movement, and is an equal one for each part of the flexible where an eccentric is situated. It is necessary that the slots in the flexible

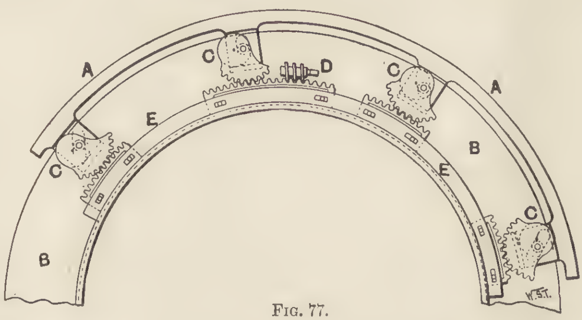


FIG. 77.

should partake of a suitable curve to allow for the difference of angular movement in the several points indicated, and it is also essential that no play or backlash should exist, otherwise the accuracy of the arrangement will be destroyed.

Our next example of a flexible is shown in Fig. 78, and is one of the most recent forms introduced. It possesses several characteristics of its own, upon which we propose to bestow a little attention. In the first place, the circular framing A differs somewhat from that usually adopted. Its upper portion is seen to be grooved out and arranged at intervals for the reception of bolts or screws C and E.

In the groove is fitted, with as perfect a sliding fit as possible, a segmental strip of metal B, which forms the flexible upon which the flats travel; several supports in

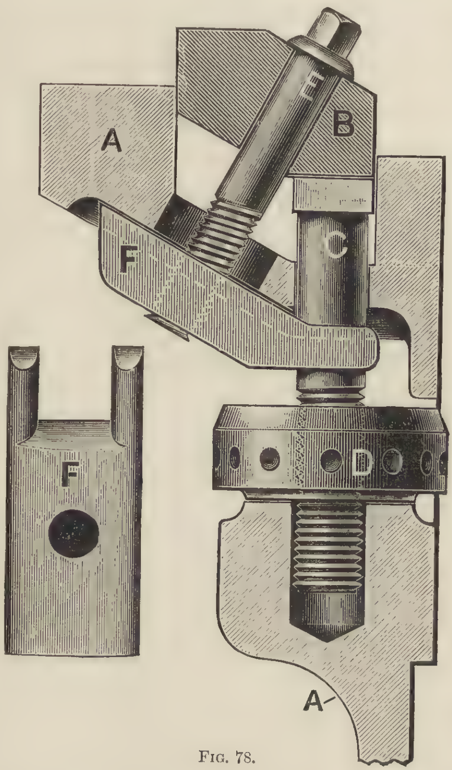


FIG. 78.

the form of screws C, at suitable intervals, are arranged, upon which the flexible rests. These screws in their turn are supported by the framing A, in consequence of their connection with the large circular nuts D. Through the medium of the several nuts D the flexible B can be raised

or lowered, and so far we have nothing essentially different from the simplest form of support for the flats. It will be noticed, however, that each support C is on one side of B, while the flats would travel on the upper surface of the flexible and considerably out from the vertical line through C. Such an arrangement means that the weight of the flats would tend to cause B to be depressed, such depression acting round the edge of the top of each support C. This depression would be prevented by the framing A, but as long as the tendency exists there must be a pressure between the two surfaces: the greater this pressure becomes the more firmly will the surface of B adhere to the surface of A, and as a result B will partake practically of the rigidity of the framing A along its whole length; so that although it is only supported at intervals by the screws C it is still strongly supported between these screws by reason of its overhanging character. The weight of the flats is not sufficient to give the necessary pressure for the purpose, nor yet to maintain the flexible on its supports; therefore a series of screws E is introduced opposite to each of the screws C, so arranged that by screwing them into specially formed nuts F the necessary pressure is easily obtained; F is forked, and fits round the turned part of C in order to prevent any movement. The setting nut D is indexed, and projects slightly through slots cut in the face of the framing A; this enables the setting to be easily performed.

To those capable of understanding the matter it may be interesting to go a little further into the subject of the sketch. We have spoken about the pressure between A and B; this pressure must act at right angles to their surfaces, so it will naturally be a horizontal one; and the pressure upon C will for the same cause be vertical. These

two pressures are merged into the one pressure produced by the screw E in its angular direction. According to this angle, we can easily tell which will be the greater pressure, that on C or that between A and B. As arranged in the drawing, the greatest pressure is on C, so if C is lowered by means of D the part of B resting on C will be lowered also. We cannot expect the whole of the flexible to be lowered, for as already pointed out, the rigidity of the pressure between A and B would certainly prevent that part of the flexible moving. This difficulty is overcome by loosening each of the screws E whenever a re-set is necessary, after which the setting is done by the nut D. The flexible is thus free to fall into its new position, and when this is obtained the screws E are again tightly screwed up, and a state of rigidity in the flexible is resumed.

The question as to whether the deflection of a flexible having supports every 13 or 14 inches is one of material consequence to the working of the card, or whether it interferes with any necessary accuracy, is one that may safely be ignored. It is certainly so microscopic an amount that it is questionable whether such a presumed advantage as its elimination is not overbalanced by the introduction of additional work in the operation of adjustment.

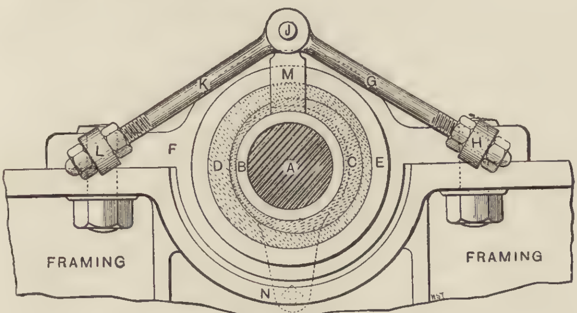
There are numerous other forms of bend or curved supports for the flats: for instance, one well-known machine, instead of a flexible bend, consists of a disc or ring that revolves upon the same centre as the cylinder. Its speed is such that it has practically the same surface-speed as the flats which travel upon its outer surface; this, of course, prevents any possible wear of either flats or flexible, because friction between them is neutralised. The lowering of the flats is brought about by milling off a little of the surface of

the ring, special and accurate arrangements being provided for this purpose. Another form has its flexible composed of several brackets, arranged to slide radially towards the centre of the cylinder. Each bracket slides within the other in angular grooves, and all are in a series and connected to each other by pins. A cover plate is connected to the middle series, and also to the centre bracket of each end. The series is adjustable, and its movement causes the whole of the brackets to move simultaneously into a smaller circle. The brackets are turned to a circle half-way between the extreme positions they will occupy when working, so the possibility of error is reduced to a minimum.

In most of the flexibles we have been considering it will have been apparent that, no matter what advantages might be claimed for the respective types, their real value would depend upon the stationary character of the cylinder centre. The flexible shown in Fig. 68 is an exception to this, because there we have an arrangement which enables it to be set so that at each point we can obtain concentricity whether the centre has moved or not; but in the other examples the simultaneous setting of the whole flexible, or the necessity existing for setting each point exactly alike, introduces the condition that the centre around which they are set must maintain its position, or else it ceases to fulfil the condition of its successful action. Several causes tend to alter the position of the cylinder centre, all resulting in the wearing of the shaft bearing, this wear taking place in various directions, according to the cause which produces it, such as the weight of the cylinder; the pull of the strap; vibration of the machine; the slightest irregularity in the balancing of the cylinder; or negligence in lubricating, etc. When such wear does take place something must be done to restore the centre to its original position, and with this

object in view several methods have been adopted which satisfactorily attain this result.

The first example is the one shown in Fig. 79. A is the cylinder shaft running in a phosphor bronze bush B, to which is cast a lug that can be set-screwed to the framing, so that it will be prevented from revolving with the shaft. This bush is contained in an eccentric iron bush C, which in its turn is also enclosed by an outer eccentric bush D, the whole arrangement being set in the loose cylinder



PATENT ADJUSTABLE CYLINDER PEDESTAL

FIG. 79.

pedestal F, which is firmly bolted to the framing of the card. Each eccentric, C and D, is formed with a projection M, and to these are attached, by the pins J, the adjusting screws G and K. The screws pass through the snugs H and L, and by their means the eccentric can be moved in any possible direction required, so that if the centre shaft A is moved in any way it can easily be restored to its original position. In order to be able to readily detect whether the centre has been disturbed, the pedestal F has turned on its face a raised portion E, which is always concentric with the flexible. By employing a suitable gauge, which is made to

fit this boss as well as the shaft A, we can detect at once whether A has moved or not; when it is found to be impossible to fit the gauge, the eccentric through the adjusting screws must be manipulated until this condition is obtained. In good machines, with bearings of the best material, it is scarcely necessary to touch the arrangement for long periods.

Our next example is given in Fig. 80. Here the cylinder

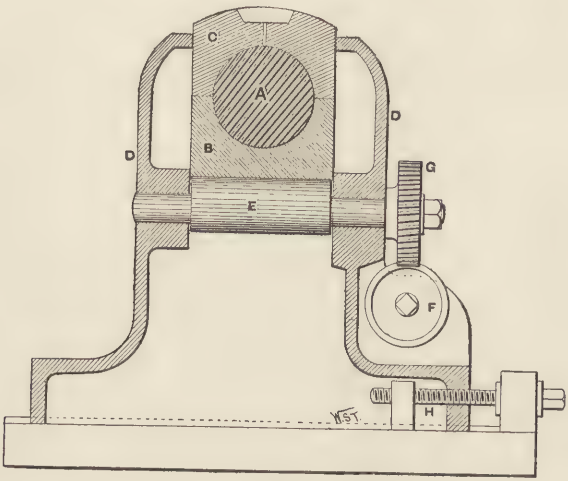


FIG. 80.

shaft A is mounted in steps or brasses B and C, which slide vertically in the pedestal D. They are fixed in position when working, the bottom one B resting upon an eccentric E, by means of which the whole arrangement can be raised or lowered. The eccentric is actuated by a worm and worm wheel F and G, so that a gradual and delicate adjustment can be made in a vertical direction. In addition to this, a lateral movement can be made by the adjusting screw at

H; a combination of the two movements will compensate for any angular displacement of the cylinder shaft.

Fig. 81 represents another method, but differs from the previous one in the manner of obtaining the vertical adjustment, the same thing being effected by the employment of a wedge or cottar A. The brasses rest upon the wedge, so that its movement in either direction gives us the necessary compensation for the vertical displacement. The horizontal

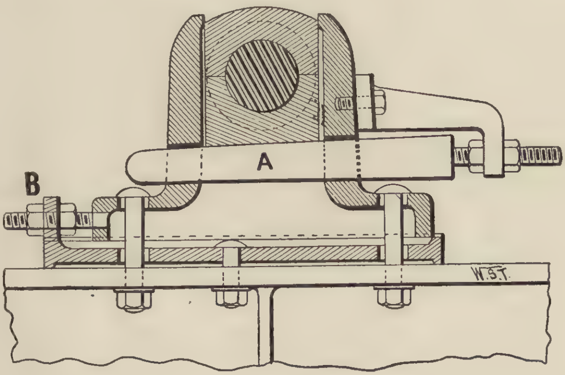


FIG. 81.

adjustment is performed in the usual way by the screw and nuts B.

The next illustration, Fig. 82, shows us another method, which makes use of a wedge to raise the centre vertically, but the lateral movement is obtained by arranging the bearing itself in such a manner that the brasses can be moved sideways by means of adjusting screws, the amount of the adjustment being denoted on a special index-plate formed on the head of the screw.

There are many other effective arrangements for obtaining adjustment of the cylinder centre based upon the

principle of the wedge, or its modification, the screw, but the examples given may be taken as characteristic of the principal ones in use at the present time.

We can now direct our attention to the cotton as it passes forward after being carded by the combined action of the cylinder and flats. When the fibres cease to be under

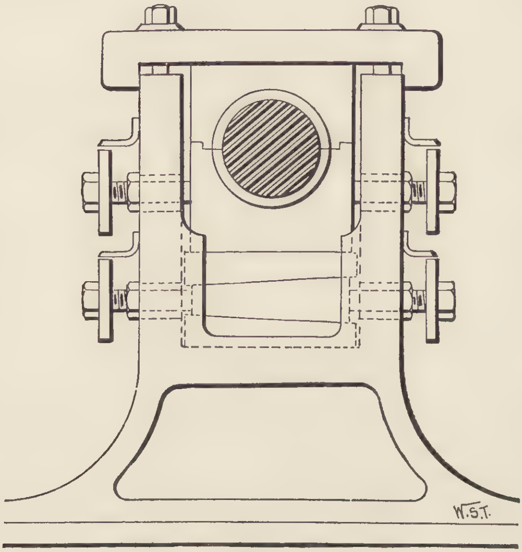


FIG. 82.

the influence of the wire of the flats, they are in a very loose and irregularly arranged condition on the teeth of the cylinder, and as a consequence offer little or no resistance to any action that tends to lift them from their position. The least draught would have this effect, but it is carefully guarded against by covering in the cylinder between the flats and the doffer. When the cotton reaches the doffer, the very close setting that is adopted enables them to

become attached to the wires, and when once this action of transferring the fibres commences, the cylinder is bound to continue it, for one fibre is crossed and recrossed by others; when one is taken away others are compelled to follow directly, or be so effected that the doffer easily catches them up. As the doffer takes the fibres from the cylinder it slowly carries them round, and this slow movement has the natural effect of causing the cylinder, as it were, to deposit the fibres in a condensed form upon the doffer, the degree or amount of the condensation of course affecting the weight per yard of the resulting web or sliver, according to the relative speeds of the cylinder and doffer. This action of the doffer may be considered its chief object, for it is scarcely necessary to point out that in any average card the carding of the cotton is completed as the cotton leaves the flats, and its condition then is such that practically nothing more is done to it except placing it on the doffer. It may possibly happen that an isolated entanglement will get between the two organs, but it is doubtful whether it will be carded in the passage. If pieces of cotton are placed on the cylinder, and allowed to go down between the doffer, they are invariably seen in the web in almost the same condition as they entered, so that we may fairly conclude that no carding (such as the action between the flats and the cylinder) takes place at the doffer. By faulty adjustment of the doffer in connection with the cylinder we can destroy what up to that point has been good carding; if too closely set, short fibres, neps, etc., may be taken from the cylinder teeth, or if set too widely apart, patchy or clouded results will be obtained owing to the doffer not taking the fibres from the cylinder regularly.

A drawing is given in Fig. 83 showing the doffer and cylinder, together with the arrangement now generally

adopted of covering them in. Sheet steel, polished both on the outside and inside, is used for these covers, and where they join between the two an almost knife edge is obtained, which very effectively prevents accumulations of fibres at this point, and so destroys that tendency to cloudiness caused through their getting on the doffer at intervals, which formerly caused so much trouble. By filling in a portion of the cover ends a receptacle or

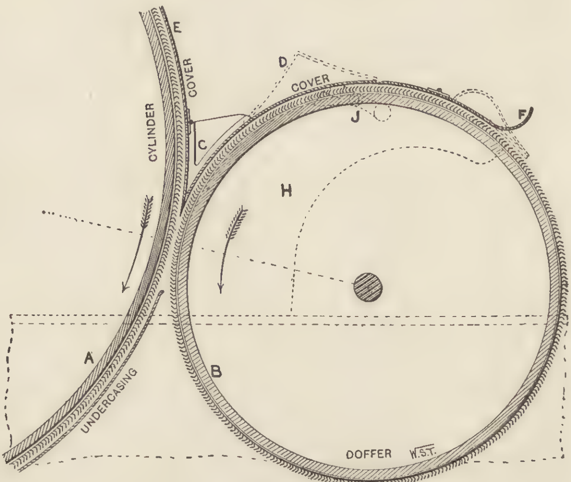


FIG. 83.

chamber C is obtained, into which the flat strippings can fall, and from which they can be collected with a minimum of trouble or waste. A great advantage of the system shown in the drawing, Fig. 83, consists in arranging the cover upon a turned segment H concentric with the doffer. It simply rests upon this segment, and also rests against a similar one on the cylinder, a catch J keeping it in position. When it is desired to test the space between the cylinder and doffer, the whole cover can be unlatched

and drawn back to the position shown at D with the slightest effort, and the same catch J will also latch it in this position. For grinding purposes the cover E can be turned down for the cylinder, whilst the end of the cover F is also hinged so that it can be turned back in the same way when the doffer requires grinding.

Since the cotton lies very loosely upon the surface of the doffer, it is a comparatively easy matter to take it off. This is effected by using a steel comb set close to the teeth, and causing it to vibrate very rapidly through a short arc of a circle, the means employed for doing this being usually an eccentric and lever. From the doffer the sheet or web is taken forward and passed between a pair of rollers called calender rollers, or sometimes between two or three pairs of fluted rollers called a draw box. From these it emerges in the form of a thick, loose rope, and is coiled very ingeniously and compactly in an upright tin cylinder by means of a small machine called a coiler, Fig. 84. The sliver is carried to the top of the coiler, and passed down a funnel-shaped hole between a pair of rollers, P. These are speeded a little quicker than the calender rollers of the card in order to keep the sliver tight. They deliver it down an inclined hole formed in the boss of the wheel L, which, when it is revolved, carries the sliver round in a circle at the point where it emerges from the hole. This action winds it in the can in a circle a little larger than half the diameter. In order that the next circle shall not lie upon the first one, the can itself is caused to revolve, and so the circles of sliver are laid side by side until the whole can is filled. It will thus be seen that in the coiler we have two distinct movements, each receiving its motion from the card through the wheel A. The coiler plate is driven from the upright shaft through the wheel K, the

same shaft also driving the calender roller through the bevels M and N. At the bottom end of the shaft a wheel D, keyed to the shaft, drives E, to which is connected F,

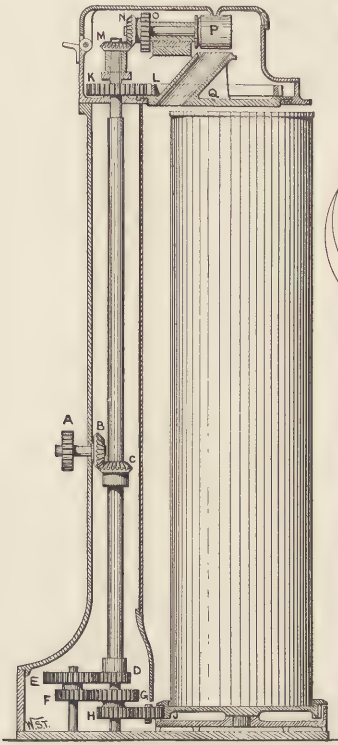


FIG. 84.

FIG. 86.

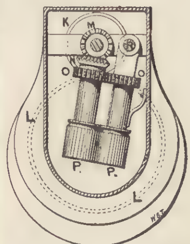


FIG. 87.

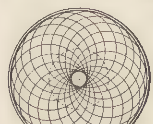


FIG. 88.

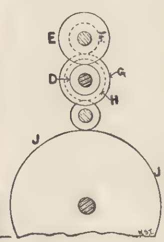


FIG. 85.

and so forms a compound carrier. F drives G, which runs loose upon the upright shaft; and H, to which it is cast, drives the can disc wheel J. A plan view of this gearing is shown clearly in Fig. 85. The whole arrangement at

the top and bottom must be geared in such a way as to obtain the most regular and compact condition for the coils, so that on withdrawing the sliver broken ends and strained portions will be avoided.

It is frequently asked if the coiler twists the sliver when laying it in the can; and the answer is often given that it does do so, but only very slightly—say, about one twist in 20 inches. Sometimes the answer is based upon the well-known appearance of the coils, but occasionally a calculation is used to show this result. Such a calculation can easily be made, but it is quite unnecessary to do so, as it is based upon finding the amount of sliver delivered to the can, and upon the number of coils placed in the can; or, what is the same thing, the number of revolutions of the wheel L. We can see that in consequence of the sliver passing down the tube it will describe a circle, and as the end in the can follows the same path, the sliver will naturally be twisted once for every coil; but when the coil is withdrawn, this twist will be usually taken out, for on uncoiling it will twist in the opposite direction to the twist put in by the coiler plate. We use the word "usually" advisedly, because this is the general arrangement, but it can happen that the twist put in when uncoiling may be in the same direction as the one put in during the coiling, and in this case a double amount of twist will be given.

The rollers P are shown in section in Fig. 86. One of them is so arranged that it can move a little on one side round the stud R as centre (Fig. 87), according to the thickness of sliver going through. A spring keeps the two rollers together, and each is driven positively. Fig. 88 represents the coils as arranged in the can, and it will be noticed that each coil goes beyond the centre of the can—

a condition which causes the whole of the coils to be well locked together.

GRINDING

The question of grinding the various organs of a card is a very important one, and its consideration has been deferred until now in order to leave the subject free from the accessory surroundings. A few of the main characteristics of the wire have already been dealt with. It now remains to add that the wire itself in its cross-section has a considerable effect in its specific action in carrying the fibres of cotton forward. Up to within a few years ago, ordinary round iron wire was used, and the grinding was performed by means of a roller covered with emery grinding on its upper surface or top. By several authorities these conditions (except that the wire now is tempered steel) are held to be the most suitable still for good work; but in view of the fact that no demonstrable difference exists when other sections of wire are used, it is doubtful whether preference can be given to round wire as the best. Various sections of wire are represented in Fig 89. A is the plough-ground wire, and is formed by grinding the sides away, almost to the bend, by special emery discs; B is the round wire; and C the so-called needle-pointed wire, in which it will be seen that only a small portion of each side near the top is ground away; D is a double convex, or, as it is sometimes called, an oval section, and is made so by rolling; E is triangular in section, and is formed in the same way. The dotted circle represents the corresponding diameter of a round wire. The arrow shows the direction in which the points of the wire travel on the cylinder, etc., and it will be noticed that the narrower part will catch the fibres first. To what extent

each of these sections can claim to do this with the best results is a point upon which opinions differ widely, but when we consider that the top of the tooth is the chief element in carrying the cotton onward, it is on this point that we ought to seek for a solution. That form which offers the greatest area (other things being equal) of catching the fibres is certainly preferable to other forms; and on this consideration the round wire is superior—for here we have a full semicircle, any point of which is in a position to catch the fibres. Other considerations, however, may modify this superiority, for there is considerable doubt in regard to the precise action of the teeth when they come to pulling asunder any entanglement, and it

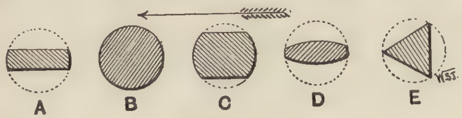


FIG. 89.

is the divergence of opinion upon this head that permits the various sections of wire to have their advocates. With the exception, perhaps, of triangular wire, they are all extensively used, and so far as experience goes little or no difference is noticeable in the results of their action.

In grinding the cylinder and doffer a Horsfall roller is used, of which an illustration will be given later, while a grinding roller, the full width of the cylinder, and having a small reciprocating motion, is used for the flats. In either case the emery, in passing over the points of the wire, causes them to bend backwards and forwards at a very rapid rate as long as the grinding continues. If the wire is not of a good quality, or its foundation not well made, the card clothing will soon break up and become useless for good work. Tempering the wire enables it to withstand

the vibration of working most effectually, and it is now the custom to temper all kinds of card wire for the sake of the extra resilience thereby obtained. The cylinder is generally ground in a position just over the doffer, whilst the doffer itself has the grinding roller applied almost vertically over its centre—these positions, of course, being chosen because they are the most convenient for the purpose. The amount of the grinding depends very much upon the experience of the man who has charge of the operation. In some mills frequent grinding (about every fortnight) of a slight character is each time resorted to, whilst in others the cards are only ground at longer intervals—say, every six weeks and upwards. It is much the better plan to grind frequently and lightly: a good point is thus preserved, and the rough action of a severe grinding is avoided.

In grinding the flats, it used to be the general practice to place the emery roller over the top of the returning flats, and grind them in this position. In striving after perfection it was discovered that the flats, resting on the flexible bend at each end, were deflected in the middle through their own weight, so that instead of a straight surface of wire it thus became slightly convex: as they returned over the top the wire surface would be upwards, and the deflection would, of course, exist here also, but in the opposite direction, so that a concave surface would be the result. A grinding roller would straighten this surface, and the natural effect of its doing so would be to increase the convexity of the flat when it came round to the cylinder again. This state of things is undoubtedly an evil, and so we find that various remedies have been adopted, both for strengthening the flat and also in applying the grinding apparatus in positions where the deflection could be neutralised. One of these antiflexion grinding motions is

shown in Fig. 90. The grinding roller is placed under the flats at the point where they are about to enter upon their work on the cylinder. In this position they have their wire downwards, and are in practically the same position

Fig. 90.

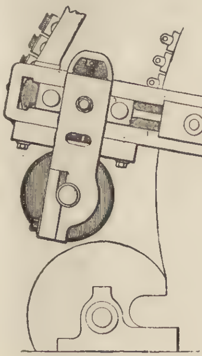


Fig. 91.

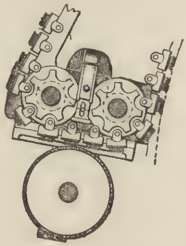
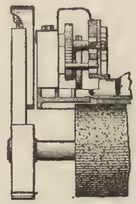


Fig. 92.



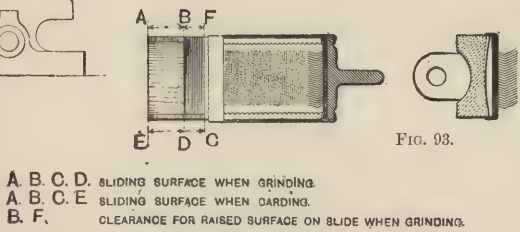


Fig. 93.

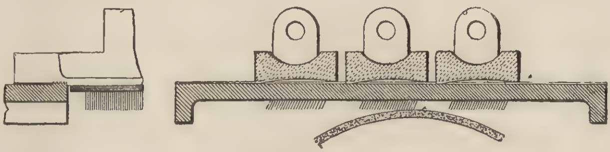


Fig. 94.

as when working, their deflection giving them a convex surface. The grinding roller grinds this surface perfectly straight, and in this condition they work, and there is no doubt that better results are obtained in consequence.

Another feature must be carefully observed in connection with this grinding operation. We have previously alluded

to and illustrated the heel-and-toe characteristic of the flat. In grinding, this must be carefully preserved, and, as the wire surface is not parallel to the travelling surface of the flat end, special surfaces must be formed for the flat to work upon in passing under the emery roller, so that the grinding takes place parallel to the wire teeth. In our sketch, Fig. 91, instead of the usual flat bowl there are two smaller ones, geared together so as to work regularly. The space between them is utilised to form a kind of bed for the flat to travel upon during the grinding (see also Fig. 94). This bed is made with a narrow raised strip, and the flat ends contain a corresponding recess, so that directly a flat comes upon the bed it is tipped up a little, and the necessary inclination for the heel and toe is obtained. The details of the motion are clearly shown in the drawings, Figs. 90, 91, 92, 93, and 94. An arrangement is given in Fig. 95, and though not used as an antiflexion motion, is still very serviceable as a means of grinding the flat to its correct inclination. The flats travel forward, and in doing so the portion D comes into contact with one end E of a lever F. An incline permits the flat to go forward, but directly it begins to move along the surface of E the pressure obtained by the weight on F presses it against an inclined sliding catch-piece G, which contains the required angle for grinding. In this position it passes on and is ground, and at the same time it moves G along with it until it is released by an inclined stop cast upon the fixing. Immediately the inclined catch G is released, it returns to its original position in consequence of the action of the weighted quadrant-lever J, to which it is connected through the toothed rack C.

Before leaving this part of the subject we may state that the stripping of the cylinder and doffer is performed

by a wire brush, which has the additional effect of burnishing the teeth and partially freeing them from any roughness they may have on their surfaces. The operation is usually performed two or three times a day, but varies according to the character of the cotton used and the quantity being carded.

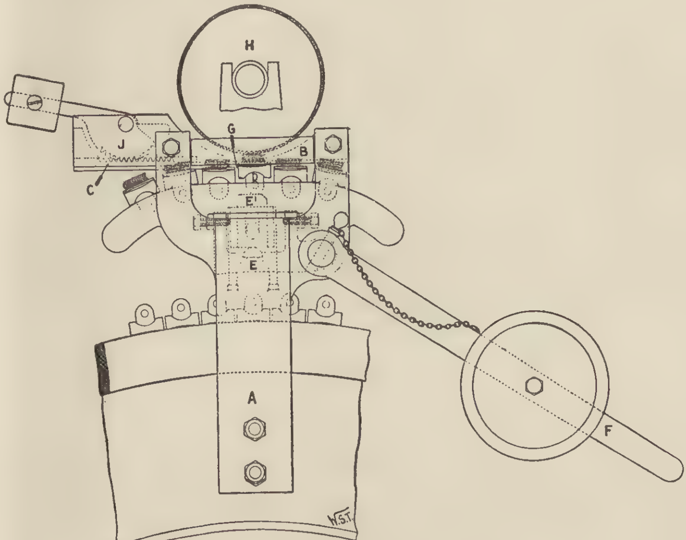


FIG. 95.

The Horsefall roller, which has already been mentioned, is represented in the accompanying drawing, Fig. 96. It has a grinding disc A, covered with emery. This disc slides upon a steel tube B, having a slot C cut longitudinally throughout its length. Within the tube B is a combined right and left handed screw D, the disc being connected to this screw by means of a fork E, which passes through the slot C. It will be seen that by fixing a pulley F on the

end of the tube B it can be driven at whatever speed is desired, and if the screw D remains stationary a very quick traverse motion will be given to the disc; but if the screw is driven by means of the pulley G fixed on its shaft, the traverse of the disc can be increased or diminished at will. The two threads on the screw combine at each end, so that a constant to-and-fro motion is given to the disc.

The gearing of the card may now be considered, and for this purpose two drawings, each complete in itself, are given. One is an elevation of the driving, Fig. 97, the

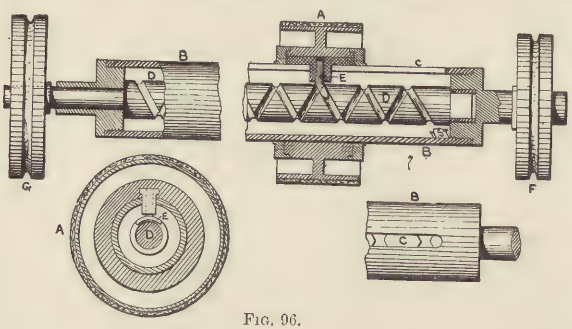


FIG. 96.

other, Fig. 98, being a plan view showing the relative positions of the various wheels and pulleys side by side. The machine is driven from the line shaft through the pulley F. From here the motion is taken by belt to the taker-in V, the other end of which transfers it to the barrow pulley H, and on through a train of wheels the doffer X. The feed roller is driven from the doffer through the side shaft and suitable gearing. The flats are generally driven in the manner shown in the sketch, though several methods have been tried to do it more directly—chiefly by the employment of epicyclic trains of wheels—but hitherto little success has attended the efforts made in this direction.

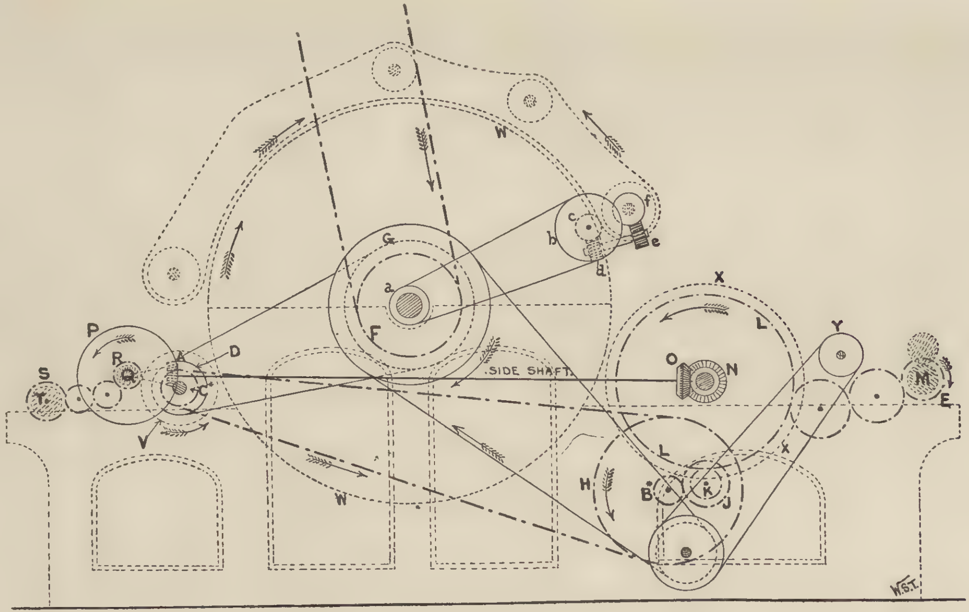
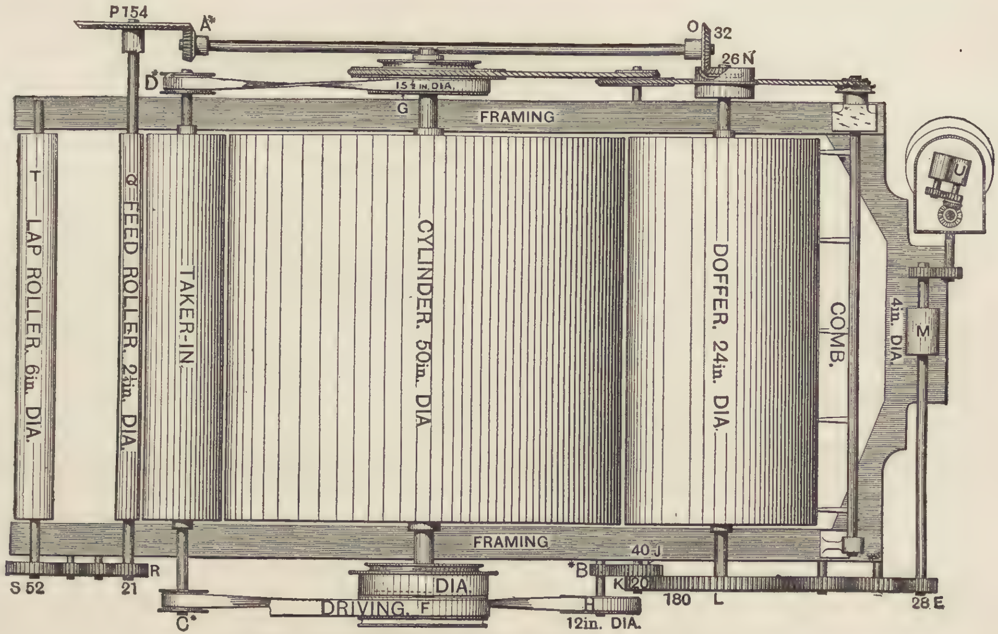


Fig. 97.



PLAN OF GEARING OF REVOLVING FLAT CARD.

Fig. 98.

Slight variations to the gearing represented in the drawing exist in other makes of the machine, but these will not affect the principle of the calculations, and the rules can be easily modified to suit any differences that may exist.

The following table of particulars will be of use in putting to a practical test the formulæ that are given :—

A	Side shaft wheel	. 10 to 40 teeth, say	= 18 teeth
B	Barrow wheel	. 16 to 40 teeth ,,	= 26 ,,
C	Taker-in pulley	. 3 to 6 in. dia. ,,	= 6 in. diam.
D	,, ,,	5 to 10 in. diam. ,,	= $6\frac{1}{2}$,,
E	Calender block wheel		= 28 teeth
F	Driving pulley	say	= 18 in. diam.
G	Taker-in driving pulley		= $15\frac{1}{2}$,,
H	Swing lever pulley		= 12 ,,
J	Compound carrier		= 40 teeth
K	,, ,,		= 20 ,,
L	Doffer wheel		= 180 ,,
M	Calender roller		= 4 in. diam.
N	Side shaft driving bevel wheel		= 26 teeth
O	,, bevel wheel		= 32 ,,
P	Feed roller wheel		= 154 ,,
Q	Feed roller		= $2\frac{1}{4}$ in. diam.
R	Lap roller driving wheel		= 21 teeth
S	Lap roller wheel		= 52 ,,
T	Lap roller		= 6 in. diam.
U	Coiler calender roller		= $2\frac{1}{8}$,,
V	Taker-in	. Diameter on wire	= $9\frac{3}{4}$ in. ,,
W	Cylinder	,, ,,	= $50\frac{3}{4}$,,
X	Doffer	,, ,,	= $24\frac{3}{4}$,,
Y	Comb pulley		——
a	Flat driving pulley	$3\frac{1}{2}$ to 7 in. diam., say	= 5 in. diam.
b	,, ,,		= 12 ,,
c	Bottom worm		= Single
d	Worm wheel	12 and 17 teeth, say	= 17 teeth
e	Top worm		= Single
f	Worm wheel		= 40 teeth
	Speed of cyl., 130 to 180 revs. per min.,	. say	= 160 revs.
	,, comb		1600 to 2000 revs.

It will be seen that four change-places are shown in the

drawings, all of which affect either the production or the weight of a given length of sliver.

By changing the wheel A, the production and draft are altered, as well as the weight of a given length of sliver. The speed of the doffer is not interfered with by the change, but the web is heavier or lighter according to the change made.

By changing B, C, D, or H, the production is changed without affecting the draft.

By changing D, and also changing C in the opposite proportion, nothing is affected except the speed of the taker-in.

The draft can be altered by changing B, C, or H, and then changing A in the opposite proportion.

To any one acquainted with the manipulation of gearing, a variety of combinations can be obtained, according to the change wheels or pulley in hand at the time.

$$(1)\ \left.\begin{matrix}\text{Total}\\ \text{draft}\end{matrix}\right\} = \frac{S \times P \times O \times L \times \text{diam. of } M}{R \times A = N \times E \times \text{diam. of } T} = \frac{52 \times 154 \times 32 \times 180 \times 4}{21 \times 18 \times 26 = 28 \times 6} = 111 \cdot 7$$

$$(2)\qquad \text{Revs. of } T = \frac{\text{Revs. of } W \times G \times C \times B \times K \times N \times A}{D \times H \times J \times L \times O \times P}$$

$$= \frac{160 \times 15 \cdot 5 \times 6 \times 26 \times 20 \times 26 \times 18}{6 \cdot 5 \times 12 \times 40 \times 180 \times 32 \times 174} = 0 \cdot 528.$$

$$(3)\qquad \text{Surface speed of } T = 0 \cdot 528 \times 6 \times 3 \cdot 1416 = 9 \cdot 95 \text{ in. per min.}$$

$$(4)\qquad \text{Revs. of } M = \frac{\text{Revs. of } W \times G \times C \times B \times K}{D \times H \times J \times E}$$

$$= \frac{160 \times 15 \cdot 5 \times 6 \times 26 \times 20}{6 \cdot 5 \times 12 \times 40 \times 28} = 88 \cdot 57.$$

$$(5)\qquad \text{Surface speed of } M = 88 \cdot 57 \times 4 \times 3 \cdot 1416 = 1113 \cdot 45 \text{ in. per min.}$$

The total draft can be obtained by dividing the surface speed of the calender roller M by the surface speed of the lap roller T, so that by driving No. 4 by No. 3 we obtain—

(6) $$\text{Total draft} = \frac{1113 \cdot 45}{9 \cdot 95} = 111 \cdot 7.$$

The draft wheel, or feed wheel A, is obtained, according to the draft required, by working out the rule No. 1 and dividing the result by the draft wanted. For instance—

(7) $$\text{Draft wheel A} = \frac{\text{S} \times \text{P} \times \text{O} \times \text{L} \times \text{diam. of M}}{\text{R} \times \text{draft} \times \text{N} \times \text{E} \times \text{diam. of T}}$$
$$= \frac{52 \times 154 \times 32 \times 180 \times 4}{21 \times 111 \cdot 7 \times 26 \times 28 \times 6} = 18 \text{ teeth.}$$

In order to save the trouble of working out the long calculation above, it is found useful to obtain what is called the constant number. This number is the result of a calculation of No. 1, but leaving the wheel A out, and from it we can get the draft or the draft wheel.

(8) $$\text{Constant number} = \frac{\text{S} \times \text{P} \times \text{O} \times \text{L} \times \text{diam. of M}}{\text{R} \times \text{N} \times \text{E} \times \text{diam. of T}}$$
$$= \frac{52 \times 154 \times 32 \times 180 \times 4}{21 \times 26 \times 28 \times 6} = 2010 \cdot 6.$$

If this number is divided by the draft, we obtain the draft wheel; and if divided by the draft wheel the draft will be the result.

(9) $$\text{Draft wheel A} = \frac{\text{constant number}}{\text{draft required}}$$

(10) $$\text{Total draft} = \frac{\text{constant number}}{\text{draft wheel A}}$$

It will be understood that the draft between any two parts of the machine can be found by the methods given. For instance, the draft between the feed roller Q and the doffer X is found as follows :—

(11) $$\text{Draft between feed roller and doffer} = \frac{\text{P} \times \text{O} \times \text{diam. of doffer}}{\text{A} \times \text{N} \times \text{diam. of feed roller}}$$
$$= \frac{154 \times 32 \times 24 \cdot 75}{18 \times 26 \times 2 \cdot 25} = 115 \cdot 8.$$

(12) $$\left.\begin{array}{r}\text{Draft between feed}\\ \text{roller and taker-in}\end{array}\right\} = \frac{P \times O \times L \times J \times H \times \text{diam. of } V}{A \times N \times K \times B \times C \times \text{diam. of } Q}$$

$$= \frac{154 \times 32 \times 180 \times 40 \times 12 \times 9{\cdot}75}{18 \times 26 \times 20 \times 26 \times 6 \times 2{\cdot}25} = 1263{\cdot}5.$$

(13) $$\left.\begin{array}{r}\text{Draft between taker-in}\\ \text{and cylinder}\end{array}\right\} = \frac{D \times \text{diam. of cyl.}}{G \times \text{diam. of taker-in}}$$

$$= \frac{6{\cdot}5 \times 50{\cdot}75}{15{\cdot}5 \times 9{\cdot}75} = 2{\cdot}1$$

(14) $$\left.\begin{array}{r}\text{Draft between cylinder}\\ \text{and doffer}\end{array}\right\} = \frac{G \times C \times B \times K \times \text{diam. of } X}{D \times H \times J \times L \times \text{diam. of } W}$$

$$= \frac{15{\cdot}5 \times 6 \times 26 \times 20 \times 24{\cdot}75}{6{\cdot}5 \times 12 \times 40 \times 180 \times 50{\cdot}75} = 0{\cdot}042.$$

A glance at the figures will show us that the denominator is the largest factor, and, as the result shows, we have a draft considerably below 1. The exact amount below may be obtained by dividing ·042 into 1, which equals 23·8 of a reduction in the draft.

Another method that is very generally adopted in making changes on cotton machinery is the proportionate one, and is worked out by the rule of three; but care must always be exercised in noticing whether the change wheel is a driver or a driven wheel. A larger driver gives increased speed, whilst with a larger driven wheel we obtain a reduction of speed.

In working out the calculation necessary for a change in the resulting sliver of the card, we can obtain it, in the first place, from the draft provided. We know the weight or length fed to the machine, but if we know the sliver at present being worked, and a change is desired to a heavier or lighter one, a simple proportion sum will give us the necessary change, or *vice versâ*, the change wheel in the majority of cases being the feed or draft wheel A. For instance, if a 20 wheel is being used, and the resulting

sliver is 0·15 hank, what wheel shall we require for a 17 hank?

$$\frac{20 \times 0{\cdot}15}{0{\cdot}17} = 176 \text{ teeth.}$$

This result is impossible to apply, so we take an 18 wheel as the nearest one to the answer; but this will clearly not give 0·17 hank, but the following, which is slightly different:—

$$\frac{20 \times 0{\cdot}15}{18} = 0{\cdot}166 \text{ hank.}$$

This variation will be noticeable throughout spinning machinery, but does not much matter, as a slight reduction in one place may be neutralised by a corresponding increase in another; the only thing for the student to avoid is the habit of jumping at results with the idea that they are near enough for practical purpose. Exactness ought to be cultivated until an experience is obtained which is thoroughly reliable.

The hank of the sliver produced from a given weight of lap is found by dividing the weight of the lap by the draft. If this result, which is the weight in ounces of a yard of the sliver, is divided into 16 oz., the number of yards in 1 lb. is obtained. This is now divided by 840, the answer being the hank of the sliver—

Weight of one yard of lap = 13 oz.; draft = 100.

(15) Ex.— $$\frac{16 \times 100}{13 \times 840} = 0{\cdot}146 \text{ hank.}$$

To find the production of a card in 10 hours—

(16) $$\left.\begin{array}{l}\text{Production}\\ \text{in 10 hrs.}\end{array}\right\} = \frac{\begin{array}{c}\text{min. in 10 hrs.} \times \text{revs. of doffer} \times 24\tfrac{3}{4} \times 3{\cdot}1416\\ \times \text{ weight of sliver in grains per yard}\end{array}}{36 \times 7000}$$

The length of filleting, 2 in. wide, to cover the cylinder is found by—

(17) $$\frac{\text{The diam. of cyl. and width of cyl.} \times 3{\cdot}1416}{\text{Width of fillet} \times 12 \text{ in.}} = \left\{ \begin{array}{r} \text{length in feet} \\ \text{of fillet.} \end{array} \right.$$

(18) $$\left.\begin{array}{c} \text{Surface speed} \\ \text{of flats} \end{array}\right\} = \frac{\text{revs. of cyl.} \times a \times c \times e \times \text{dia. of flat wheel} \times 3{\cdot}1416}{b \times d \times f}$$

$$= \frac{160 \times 5 \times 1 \times 1 \times 8 \times 3{\cdot}146}{12 \times 17 \times 40} = 2{\cdot}4 \text{ in. per min.}$$

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